Recent results of the CMS experiment

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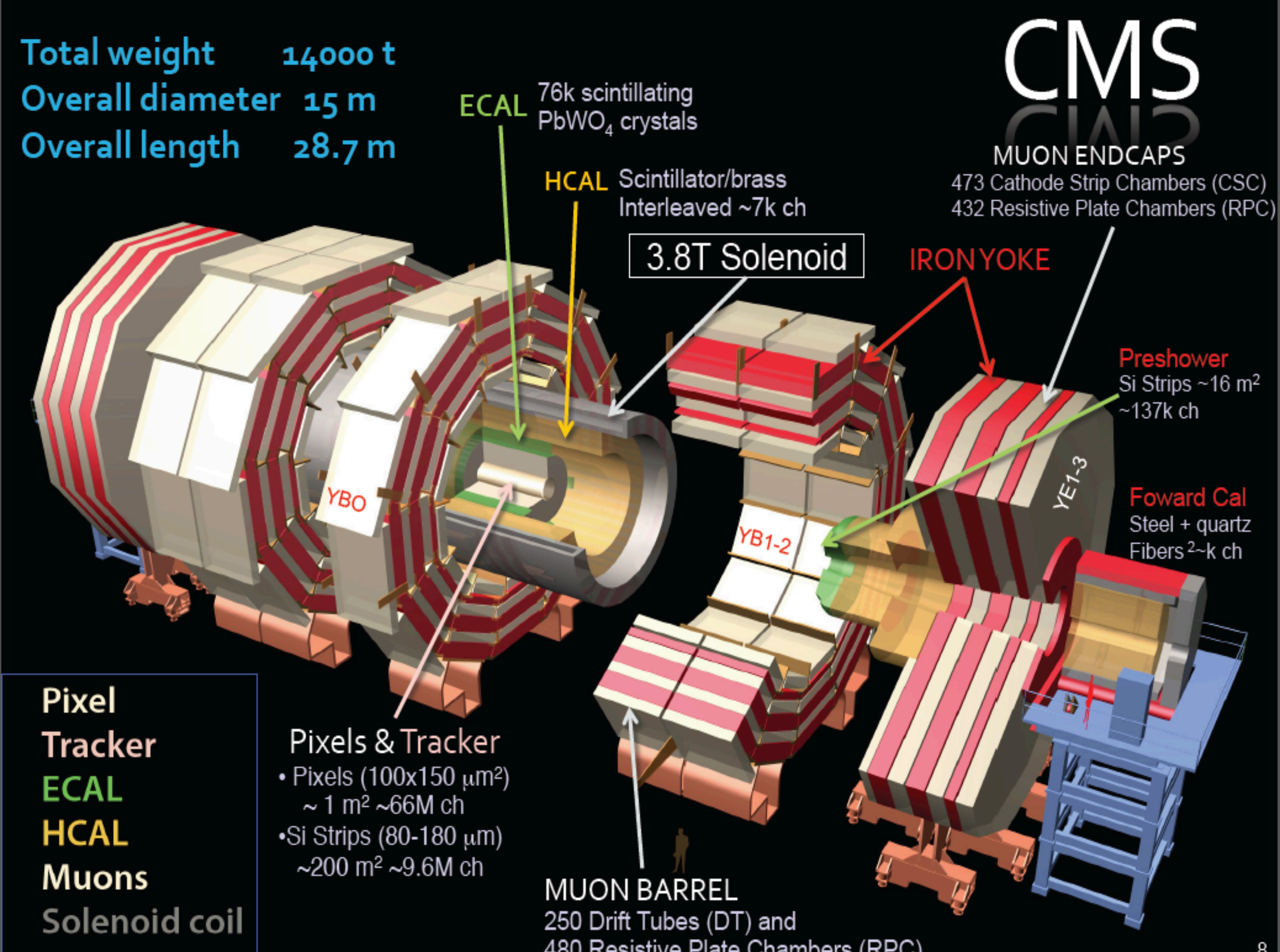
Outline

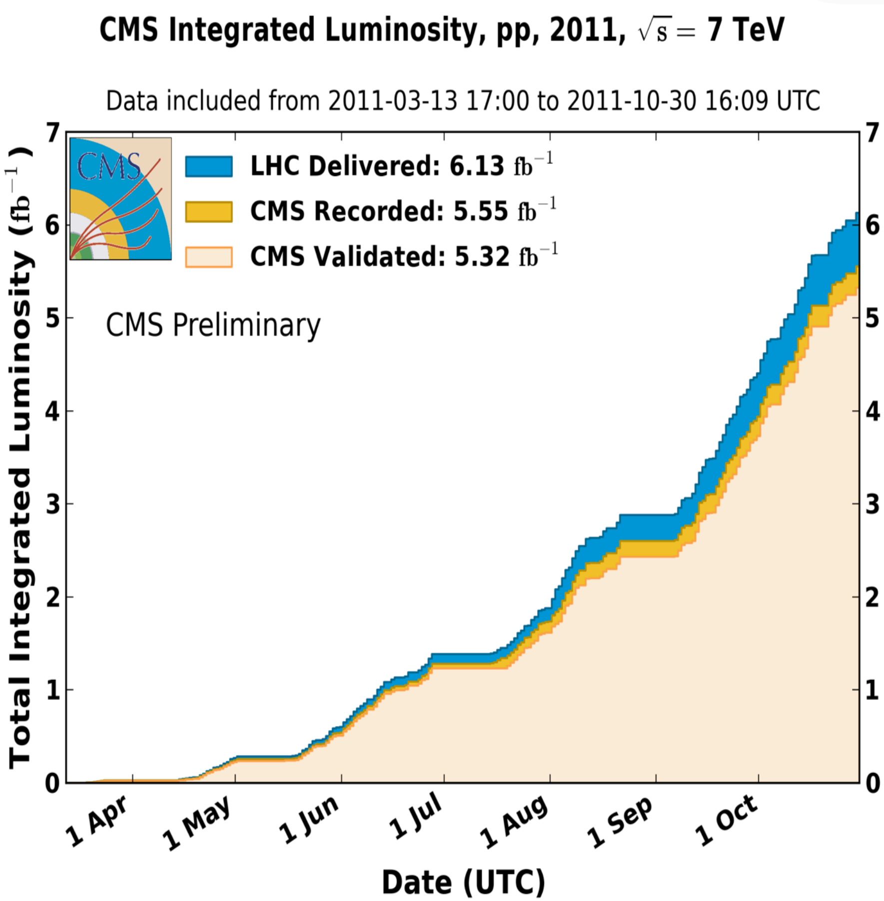
- Data and pileup
- Higgs
- Jets, vector bosons and top
- Searches
- (Heavy ions not covered)

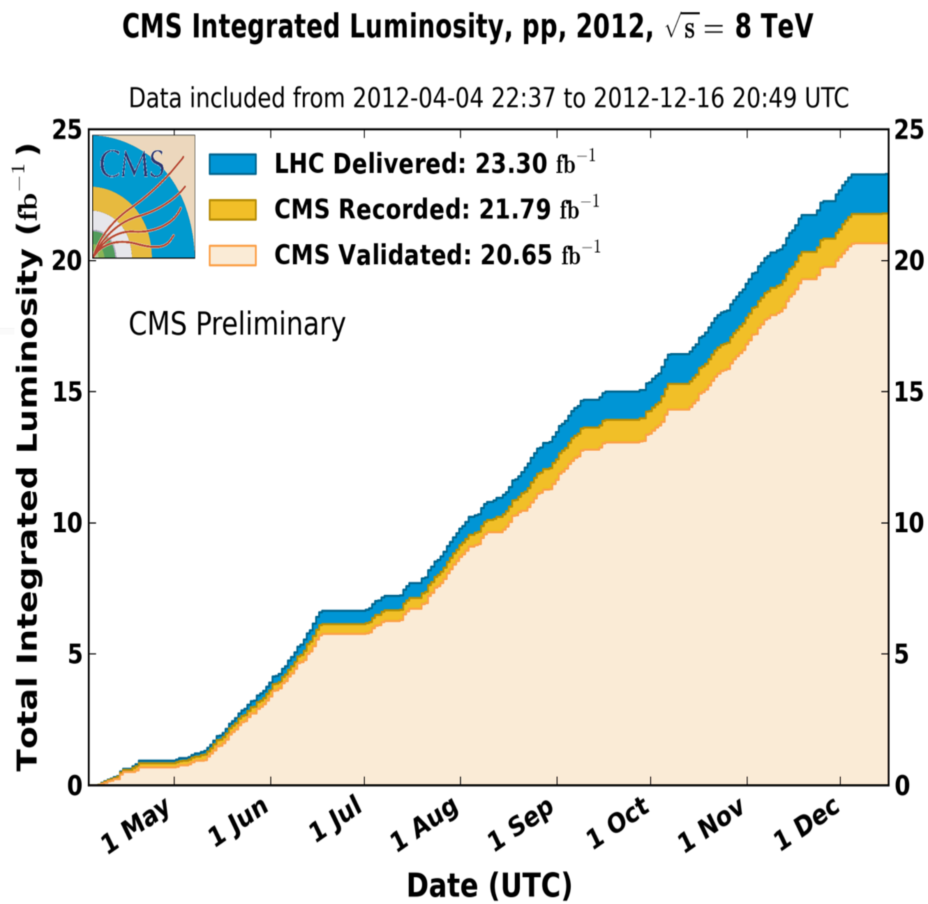


Total weight 14000 t
Overall diameter 15 m
Overall length 28.7 m
CMS
ECAL 76k scintillating PbWO4 crystals
HCAL Scintillator/brass Interleaved ~7k ch
3.8T Solenoid
IRON YOKE
MUON ENDCAPS
473 Cathode Strip Chambers (CSC)
432 Resistive Plate Chambers (RPC)
Preshower
Si Strips ~16 m²
~137k ch
Foward Cal
Steel + quartz
Fibers 2~k ch
YBO
YB1-2
YE1-3
Pixel
Tracker
ECAL
HCAL
Muons
Solenoid coil
Pixels & Tracker
• Pixels (100x150 μm²)
~ 1 m² ~66M ch
•Si Strips (80-180 μm)
~200 m² ~9.6M ch
MUON BARREL
250 Drift Tubes (DT) and
480 Resistive Plate Chambers (RPC)

Data taking in 2011-12

L = 5.3 fb^{-1} at 7 TeV
L = 20.7 fb^{-1} at 8 TeV

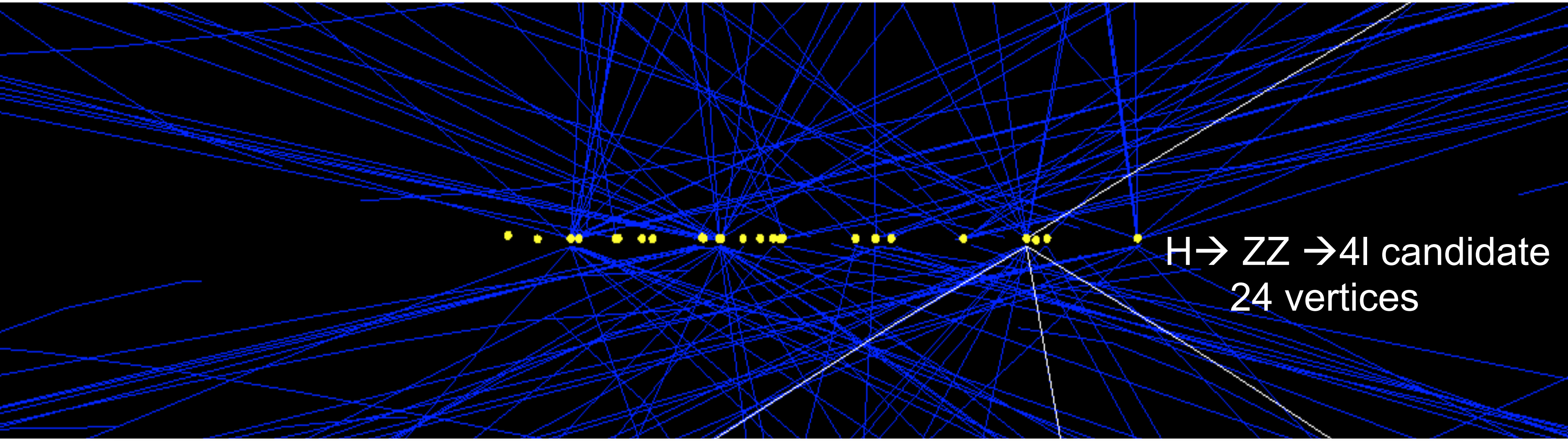


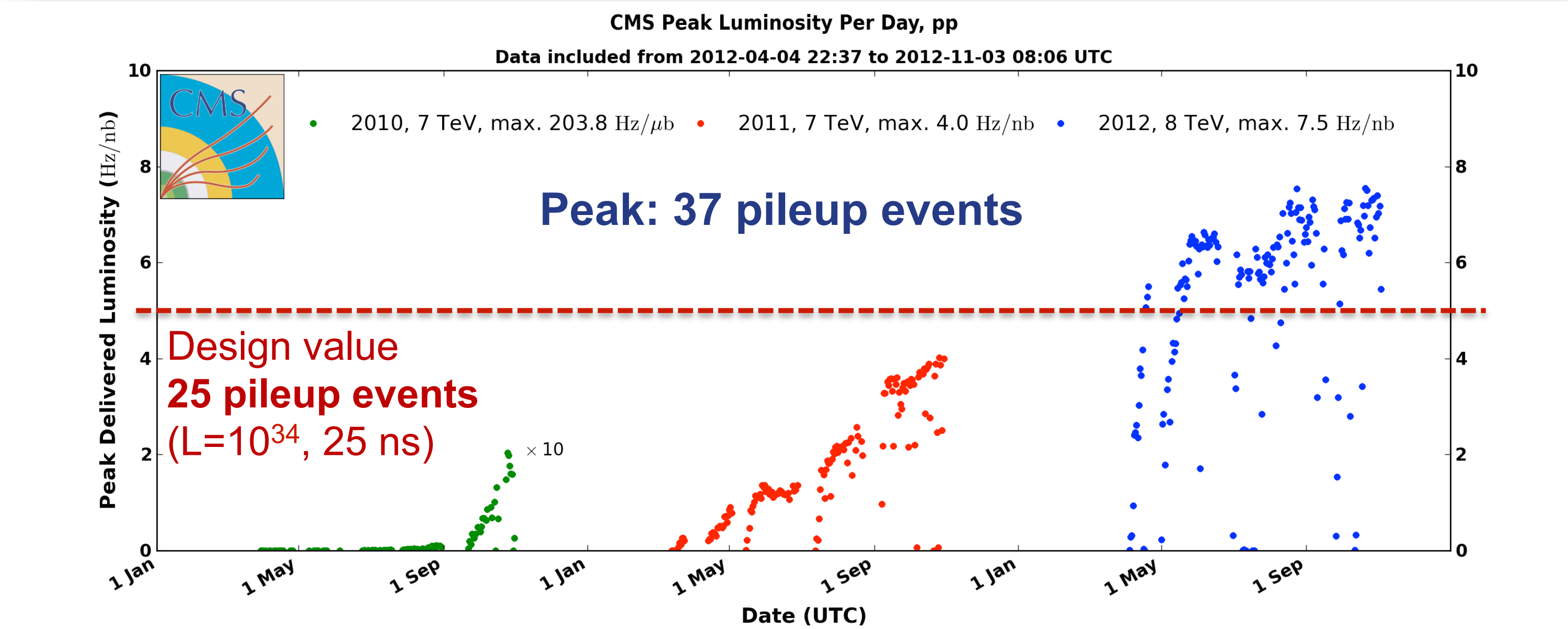


Fraction of delivered data used for physics

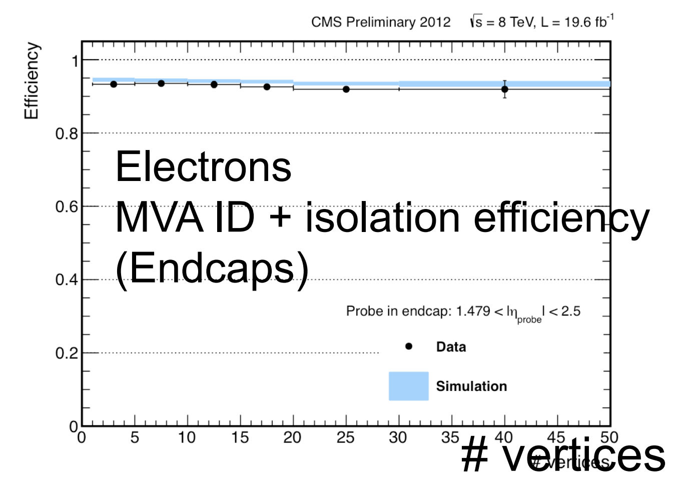
2011: 87%
2012: 89%

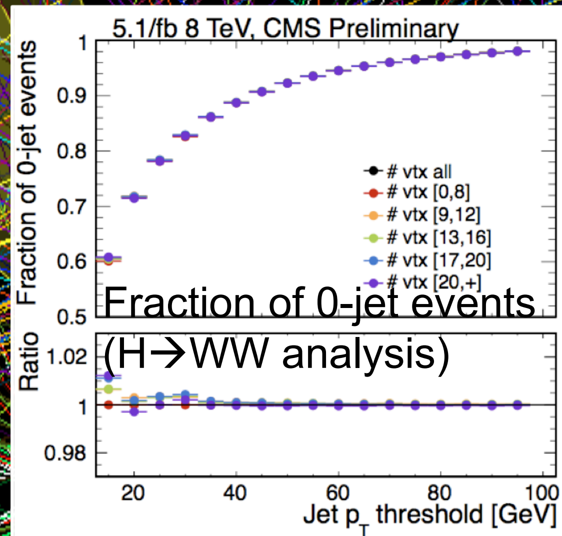
Pileup in 2012

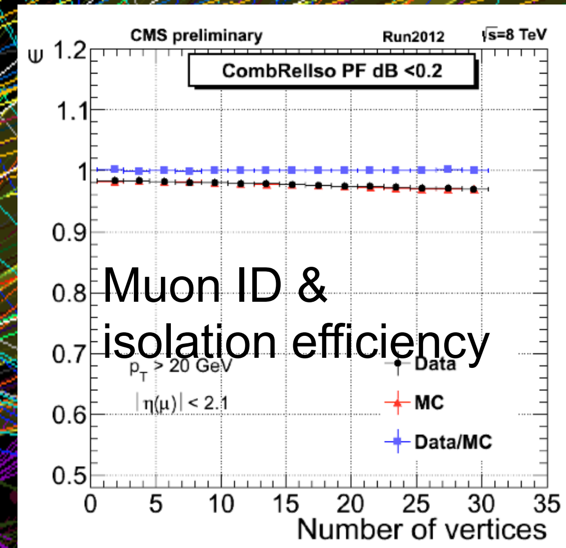


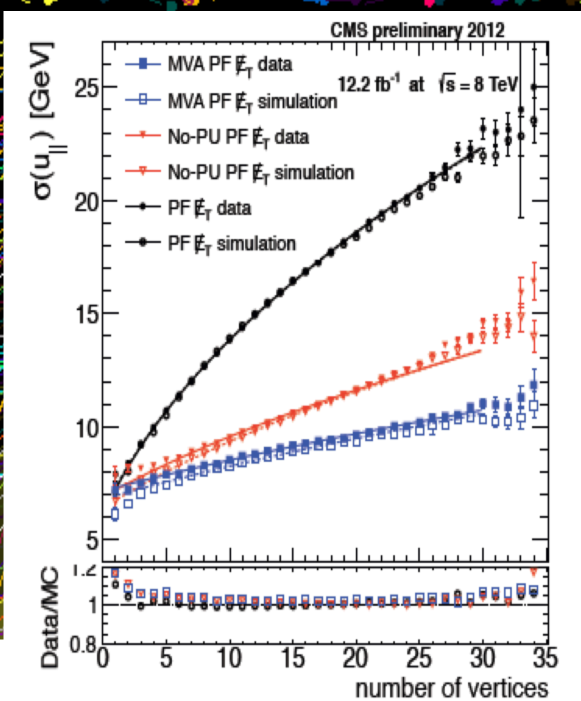


Lepton, jets, MET & pileup

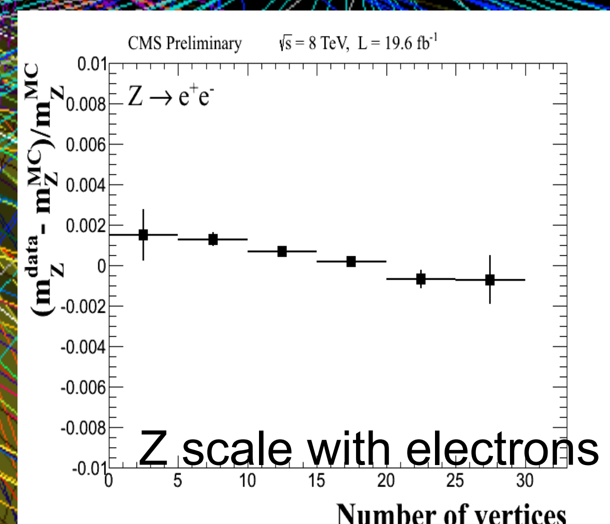




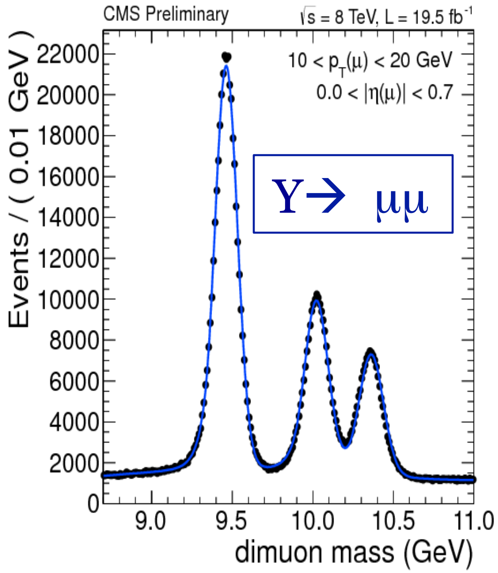


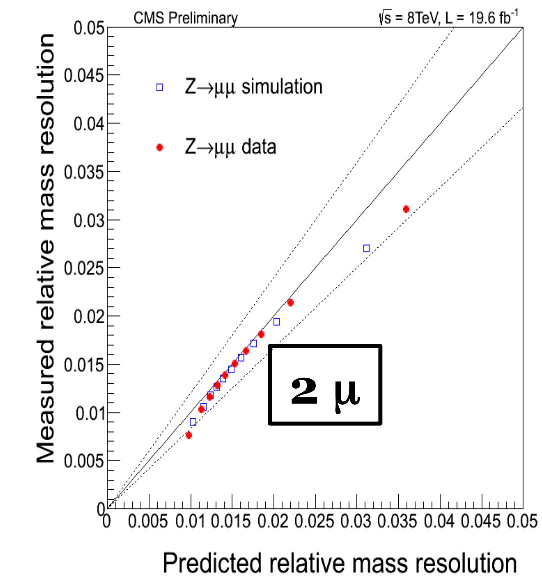


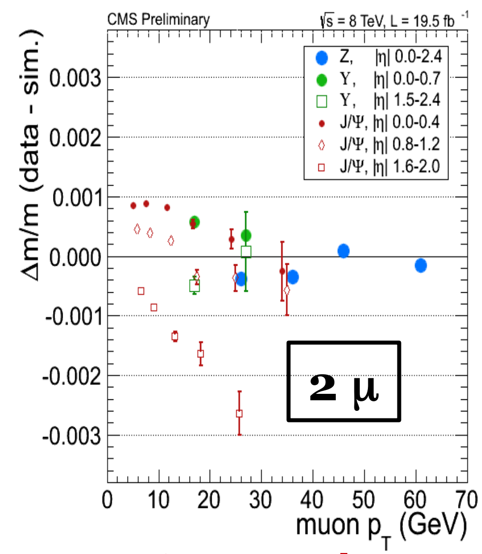
Leptons, jets and MET almost insensitive to pileup



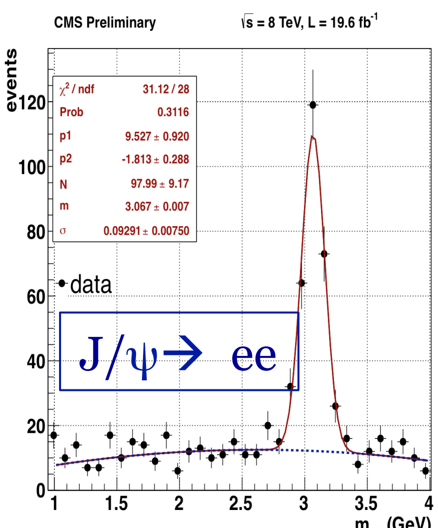
Muons & electrons

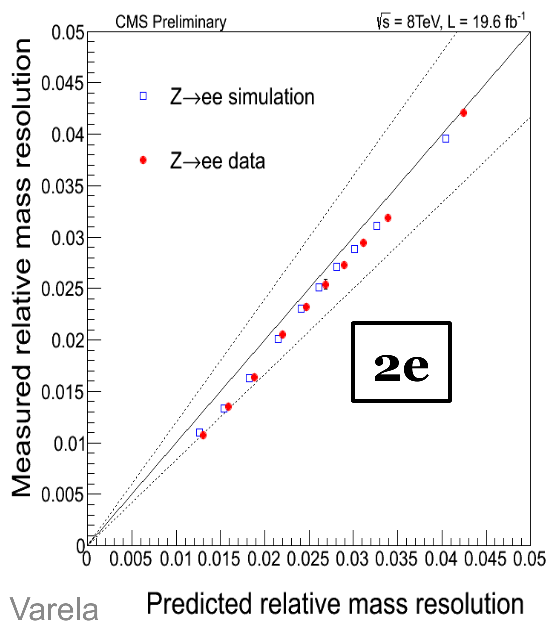


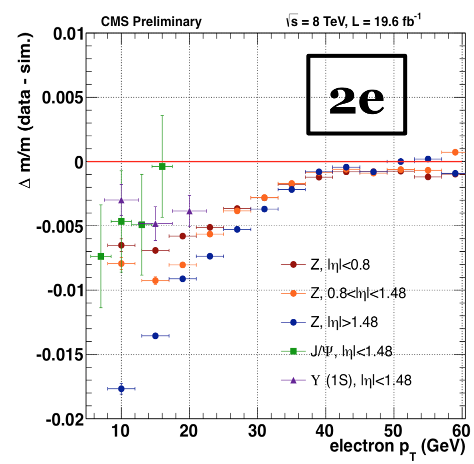




momentum scale:
0.1% for muons;
0.2% for electrons of 35<p_T<50







CMS Results for Moriond

- EXOTICA searches (7):
  - EXO-12-026 – Heavy Stable Charged Particles
  - EXO-12-027/031 –Large extra dimensions in dileptons
  - EXO-12-059 - Dijet resonances
  - EXO-12-060 - W'(lν)
  - EXO-12-061 - Z'(ll)
  - EXO-12-048 – Dark Matter, Extra Dims with monojets
- Beyond the 2nd Generation Searches (3):
  - B2G-12-012 – $T^{5/3}$ top-quark partners
  - B2G-12-010 - W'(tb)
  - B2G-12-014 - t*
- SUSY searches (3):
  - SUS-12-024 - In b-jets+MET
  - SUS-13-007 - In single-lepton + b-jets
  - SUS-13-003 - RPV SUSY in trileptons
- HIGGS studies (7):
  - HIG-12-053 - VH(ττ)
  - HIG-13-002 - H(ZZ -> 4l)
  - HIG-13-003 - H(WW -> 2l+MET)
  - HIG-13-004 - H(ττ)
  - HIG-13-006 - H(Zγ)
  - HIG-13-009 - WH(WW)
  - HIG-13-001 - H(γγ) - Twiki public
- TOP Physics (9):
  - TOP-12-015 - W helicity in ttbar dileptons
  - TOP-12-020 - W helicity in single-top events
  - TOP-12-025 - LHC combination on W helicities
  - TOP-12-027 - tt xsec at 8 TeV with l+jets
  - TOP-12-028 - tt xsec at 8 TeV with dileptons
  - TOP-12-029 - Top mass dependence on event kinematics
  - TOP-12-035 - Measurement of B(t -> Wb)/B(t -> Wq) ratio
  - TOP-12-038 - t/tbar ratio in single-top production
  - TOP-12-031 - Measurement of t - tbar mass difference
- Standard Model Physics (9):
  - EWK-11-015 - Angular correlations Z+b-jets – update
  - QCD-11-005 - Direct photon production
  - SMP-12-004 - Z/γ + jet angular distributions
  - SMP-12-005 - WW xsec 8 TeV, limits anomalous couplings
  - SMP-12-019 - Jet substructure studies-paper submitted
  - SMP-12-020 - Zγ xsec, limits anomalous couplings
  - SMP-12-025 - p_T distribution of the Z bosons at 8 TeV
  - SMP-12-002 - Measurement of W+charm
  - SMP-12-026 - Measurement of W+bb
- FORWARD and Soft QCD Physics (1):
  - FSQ-12-010 - Exclusive WW, limits on WWγγ couplings

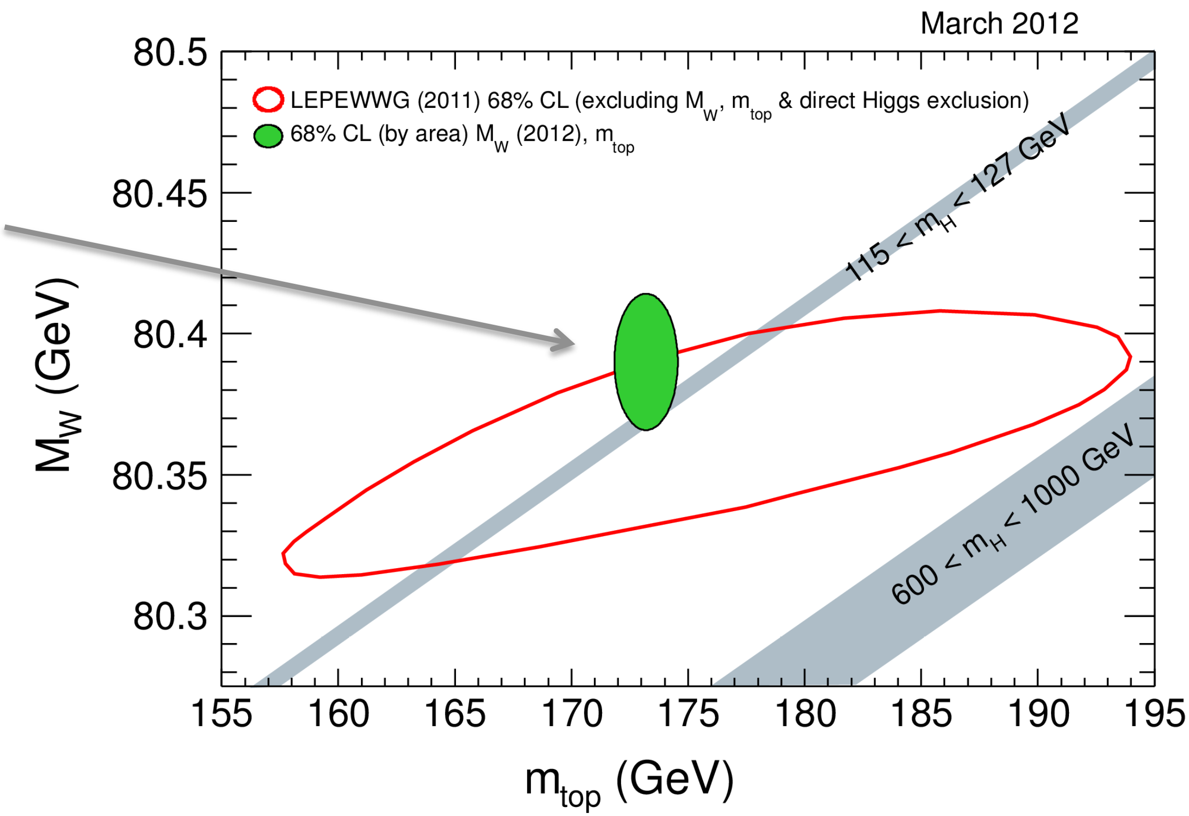
https://twiki.cern.ch/twiki/bin/view/CMSPublic PhysicsResults

Situation one year ago

Very precise measurement of M_W = 80.390 ± 0.016 GeV, driven mainly by the Tevatron.

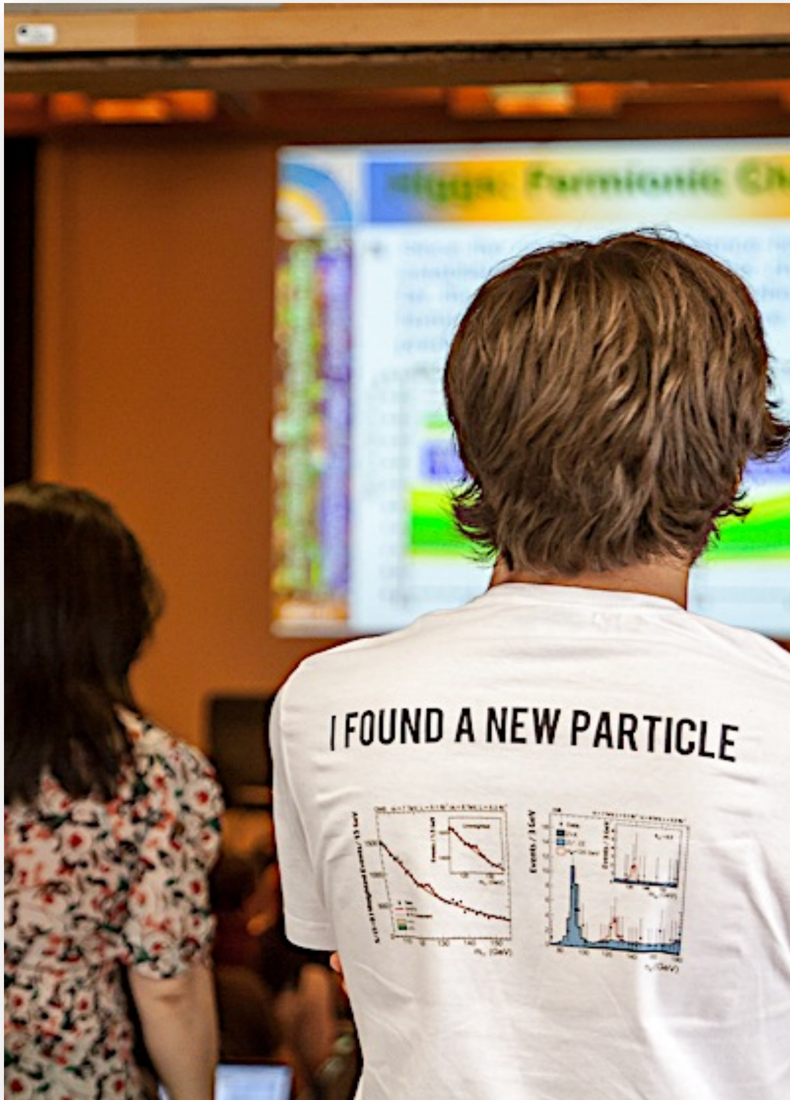
Much of the SM Higgs range had been ruled out by 2011 LHC running.

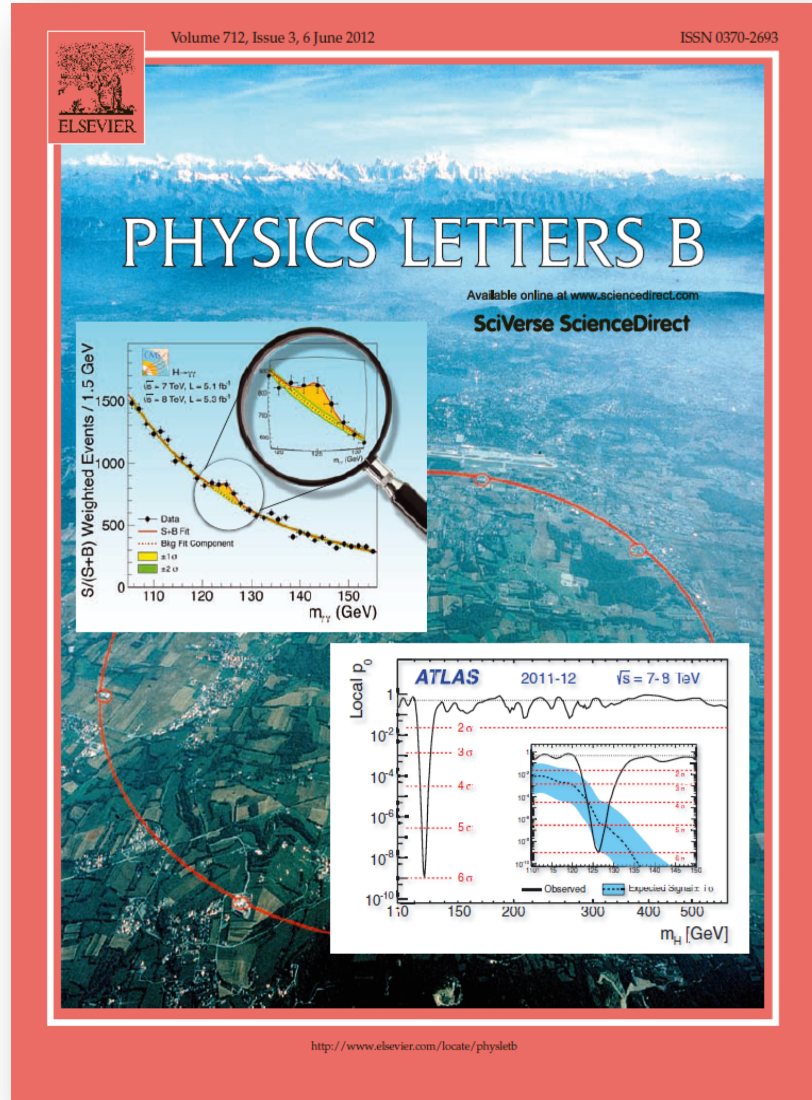
Excess of events in the low mass region seen in ATLAS and CMS



Exclusions of M_H:
- LEP < 114 GeV (arXiv:0602042v1)
- Tevatron [156,177] GeV (arXiv:1107.5518)
- LHC [~127, 600] GeV arXiv:1202.1408 (ATLAS) arXiv:1202.1488 (CMS)

Higgs discovery



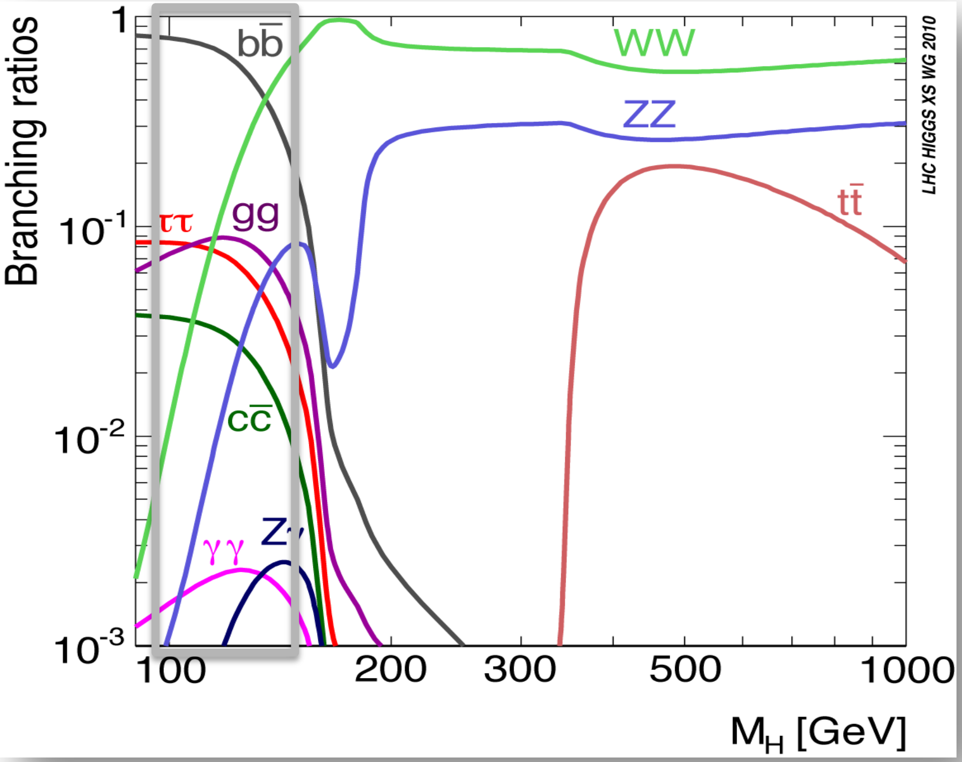


Higgs boson decays

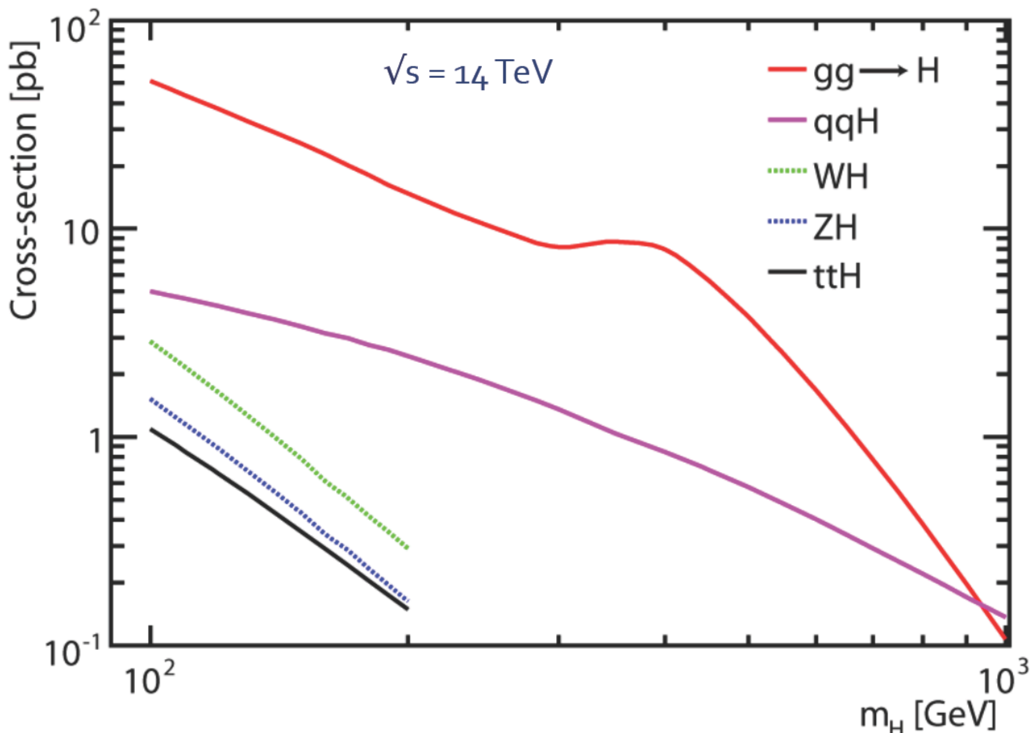
5 decay modes exploited:

	Exp Sig @125.7 GeV	σ_M/M
• bb	2.2σ	10%
• $\tau\tau$	2.6σ	10%
• WW	5.3σ	20%
• ZZ	7.1σ	1-2%
• $\gamma\gamma$	3.9σ	1-2%

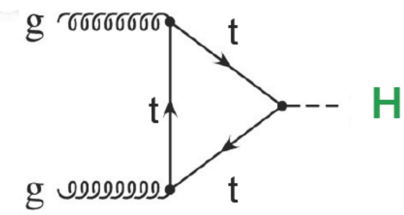
- and searches in $Z\gamma$



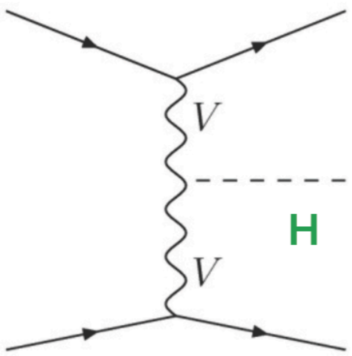
Higgs production



Dawson, Jackson, Reina, Wackeroth



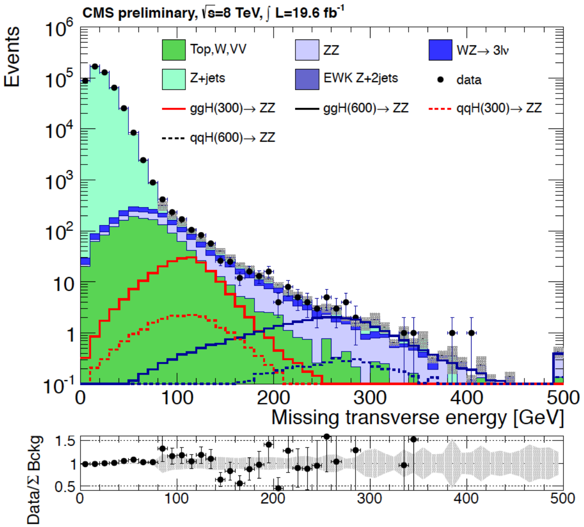
Gluon fusion



Vector Boson fusion

- Gluon fusion is dominant in the entire m_H mass range
- Vector boson fusion is the next most important

H→ZZ→2l2ν

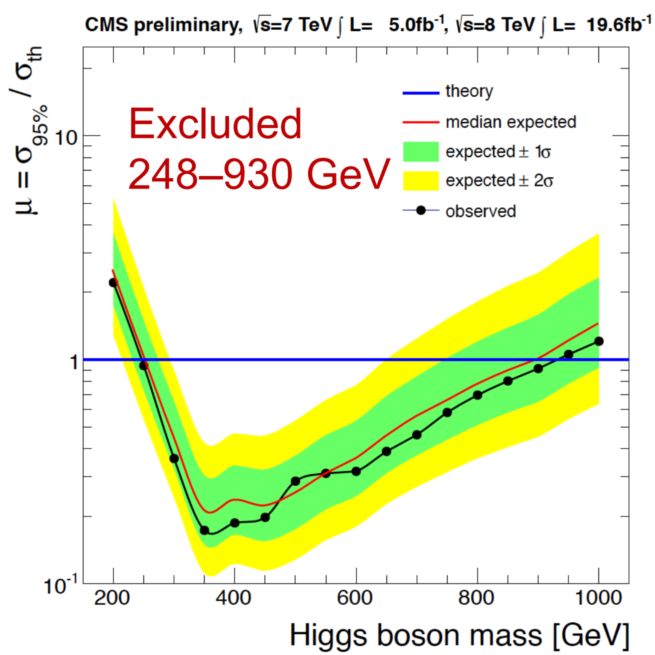


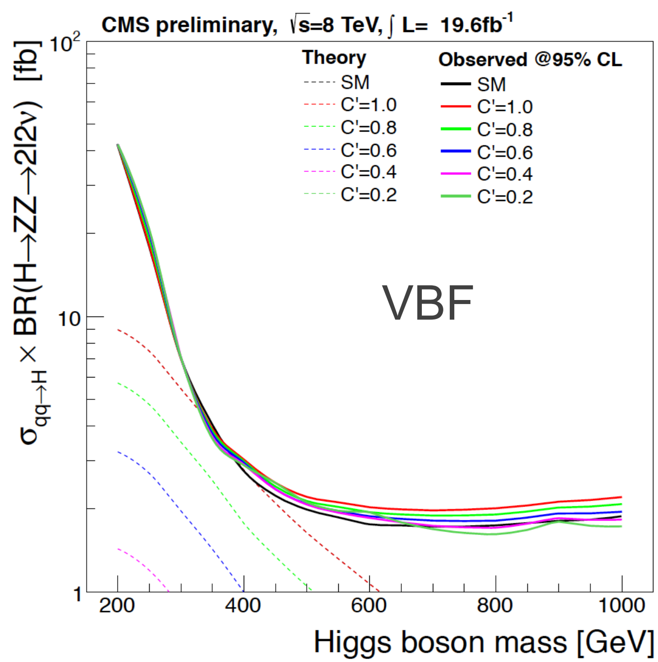
SM-like heavy Higgs boson search, mass > 200 GeV.

- Two leptons (e, μ) from one Z and large missing energy (2ν)
- Mass not reconstructed.
- Shape analysis based on missing ET and transverse mass

Re-interpretation of results as a search for an electroweak singlet scalar mixing with the Higgs 125 GeV.

- Upper limits at 95% CL on the cross section as function of mass (gg and VBF production)



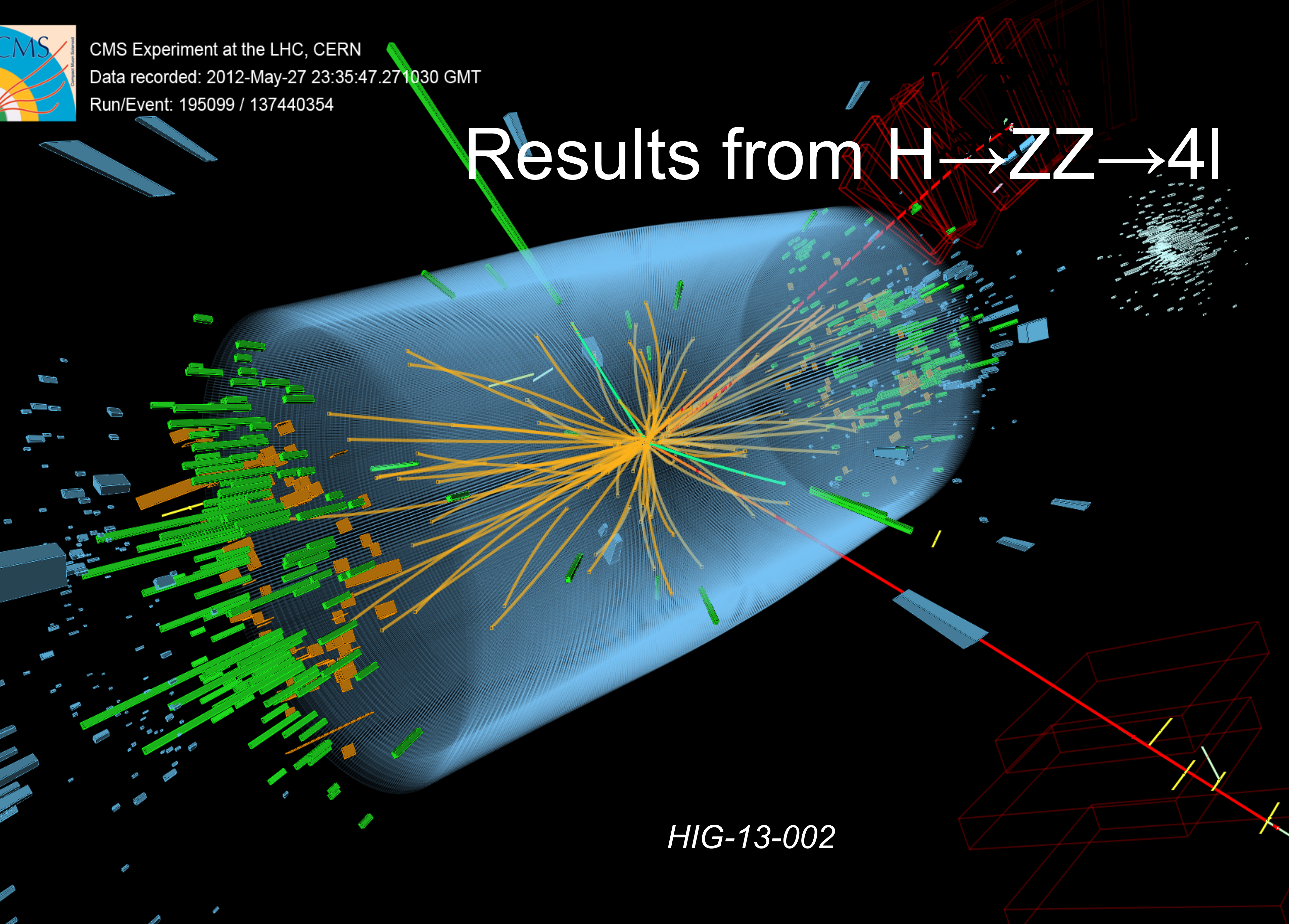


C (C') scale factor of the couplings of the low (high) mass state with respect to the SM.

Assume that the boson does not decay to new particles.

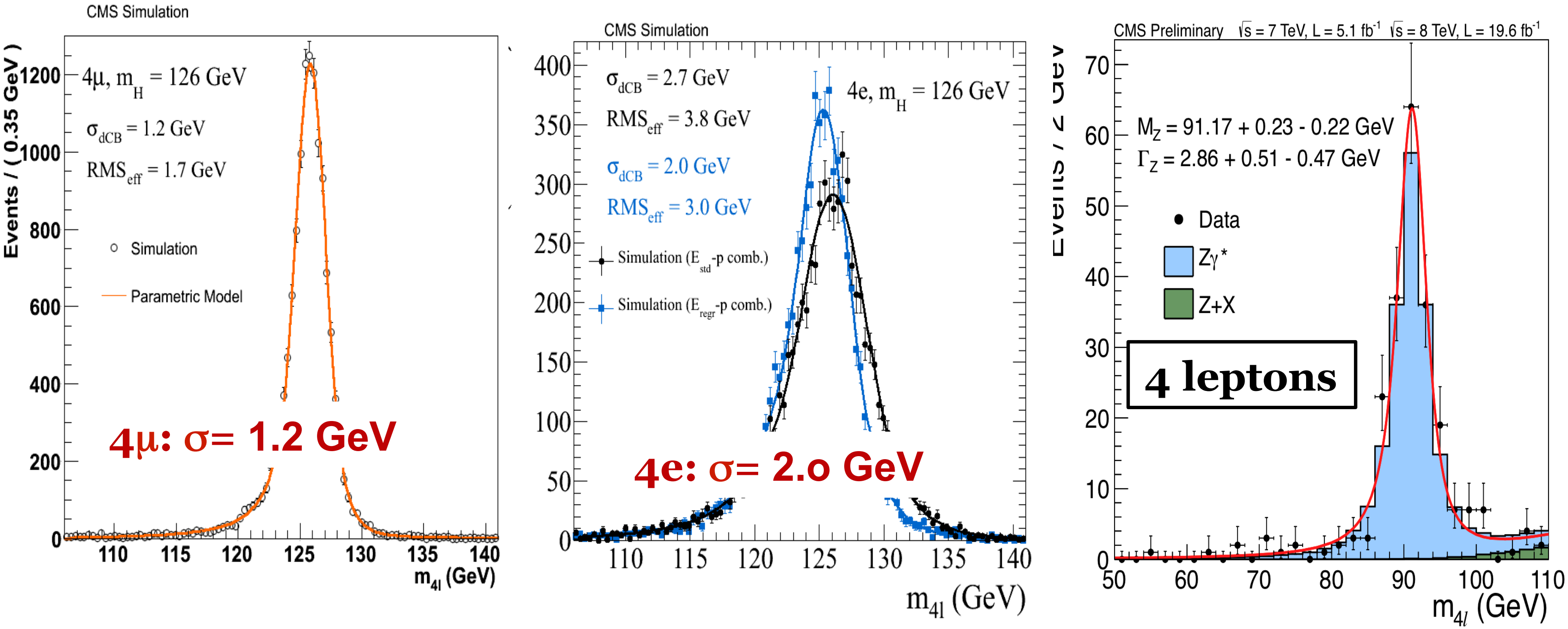
HIG-13-014

Results from $H \to ZZ \to 4l$



HIG-13-002

Four lepton mass resolution



4 lepton mass resolution = 1 – 2% with uncertainty: 20%

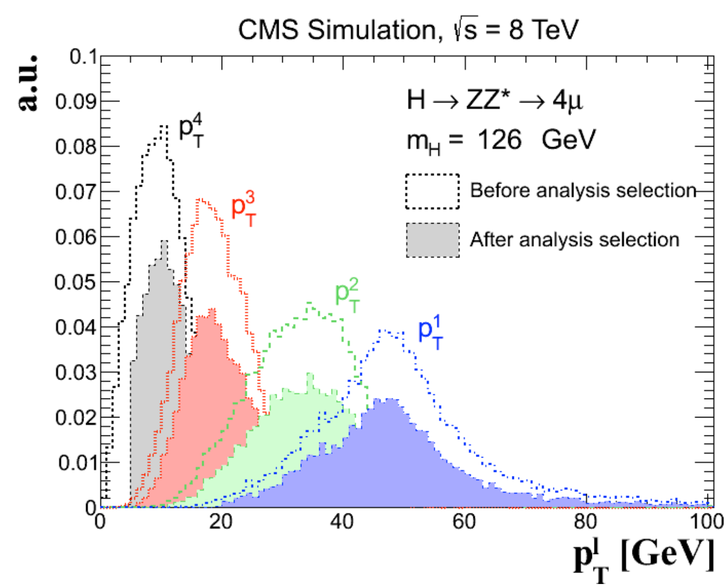
Validated in situ with Z(4l)

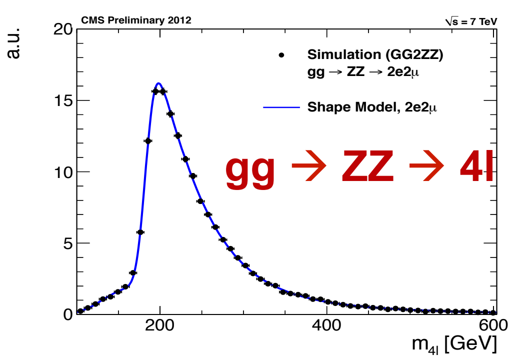
Background modeling

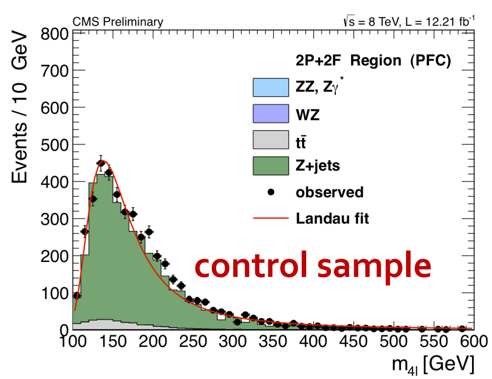
- Background models:
  - irreducible ZZ$^{(*)}$
    - Estimated using simulation
    - Corrected for data/simulation scale
  - reducible Z+jets, ttbar, WZ
    - Estimated from control samples

Event selection:

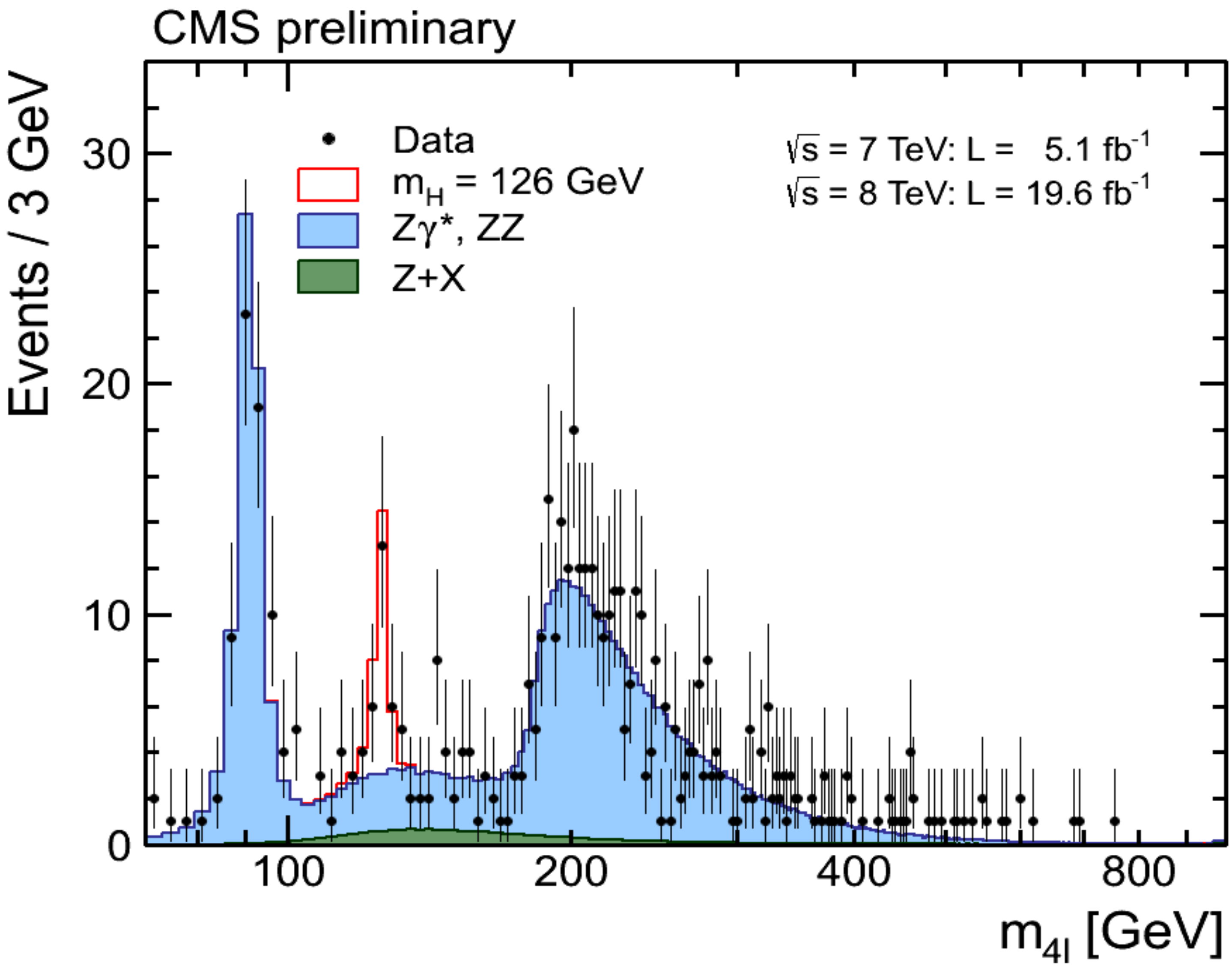
requires the highest possible efficiencies (lepton Reco/ID/ Isolation).



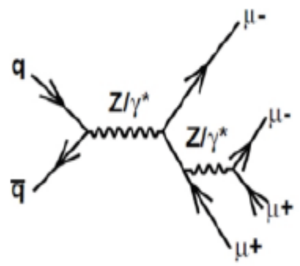


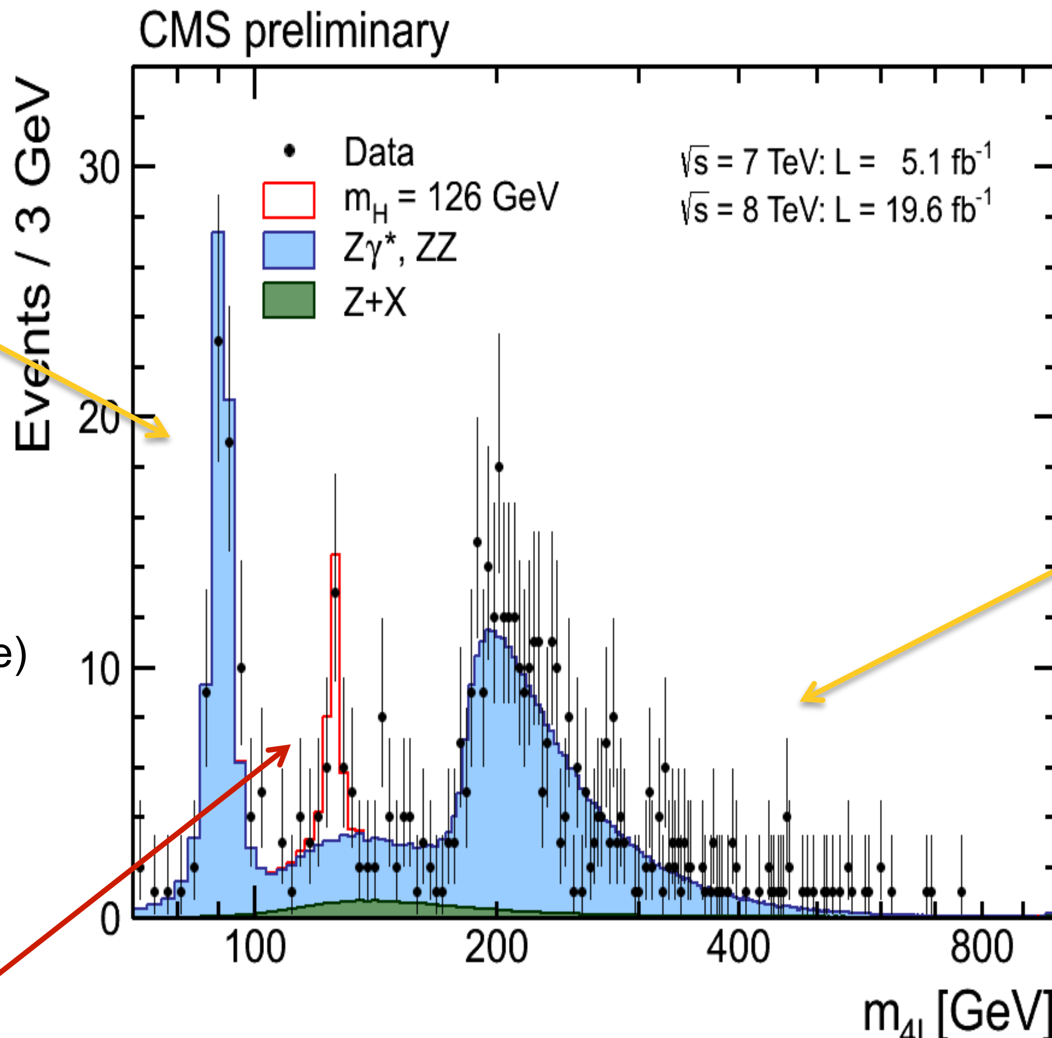


A beautiful peak



Four lepton mass spectrum





Offline selection cuts:
5 (7) GeV for μ (e) in $|\eta| < 2.4$ (2.5).

Very good control of the dominant ZZ background

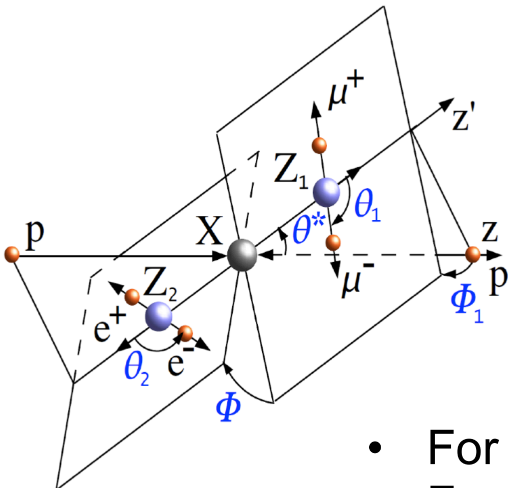
M(4l)>160 GeV
Data 380
MC 364.5

Clean signal peak at ~126 GeV

$\sigma(pp \rightarrow ZZ, 8TeV) = 8.4 \pm 1.0$ (stat.) $\pm$ 0.7 (syst.) $\pm$ 0.4(lum.) pb

$\sigma_{SM}(th) = 7.8 \pm 0.6$ pb

Kinematic discriminant



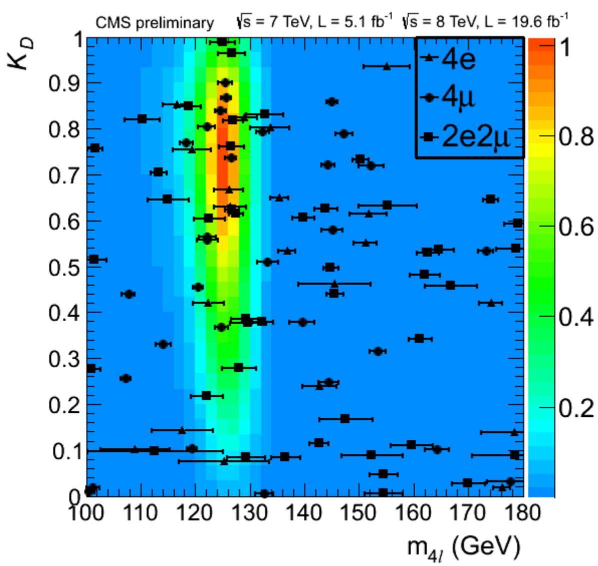
Matrix Element Likelihood Analysis:

uses kinematic inputs for signal to background discrimination

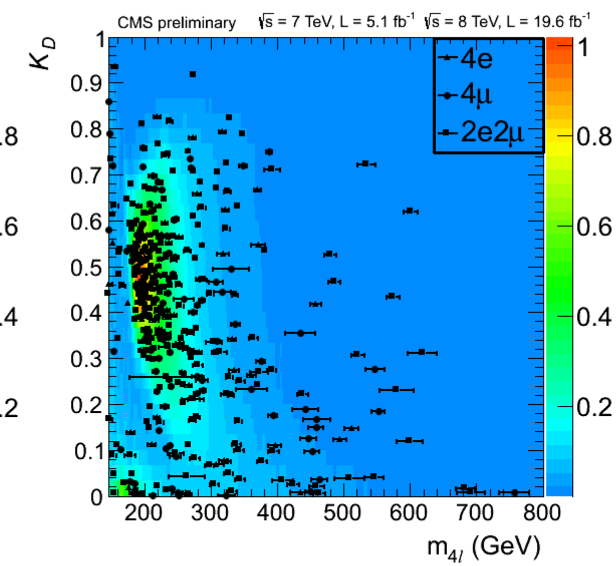
$$\{m_1, m_2, \theta_1, \theta_2, \theta^*, \Phi, \Phi_1\}$$

$$K_D = \left[1 + \frac{\mathcal{P}_{\text{bkg}}(m_1, m_2, \theta_1, \theta_2, \Phi, \theta^*, \Phi_1 | m_{4\ell})}{\mathcal{P}_{\text{sig}}(m_1, m_2, \theta_1, \theta_2, \Phi, \theta^*, \Phi_1 | m_{4\ell})}\right]^{-1}$$

- For the signal use a fully analytic parameterization
- For the background use a simulation of the process $q\bar{q} \rightarrow ZZ/Z\gamma$



Data and signal expectation for m_H = 126 GeV

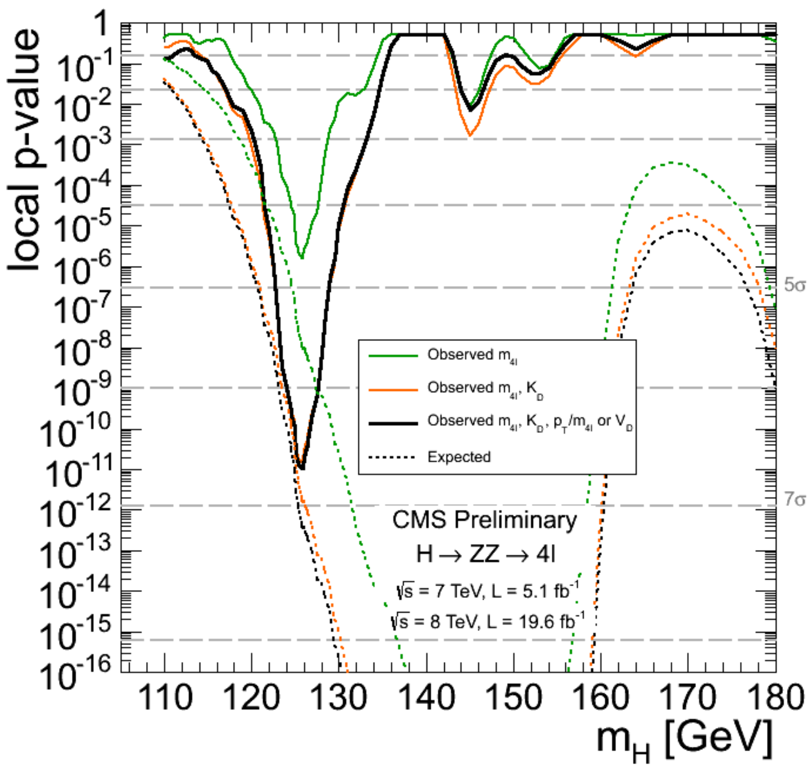


Data and background expectation

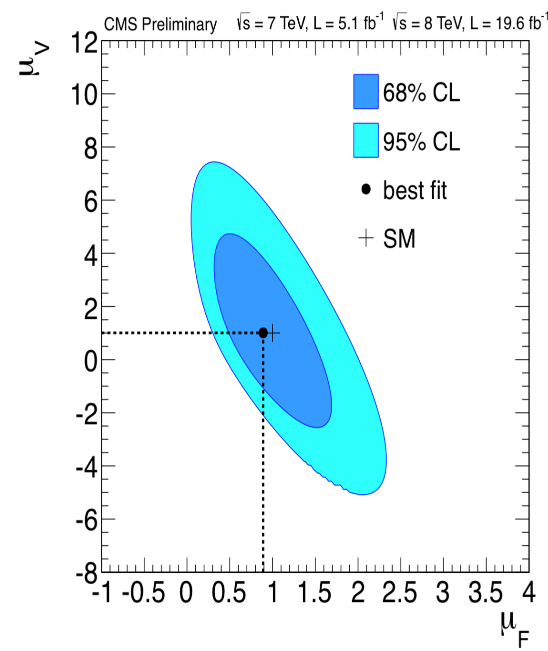
K_D distribution is similar for different signal models: $J^P = 0^+, 0^-, 1^-, 1^+, 2^+_{mgg}\ 2^+_{mqq}$

Several parameterizations of matrix elements have been studied with similar results

Results



Untagged (0/1 jets) and tagged (2 jet) categories are used to measure the couplings

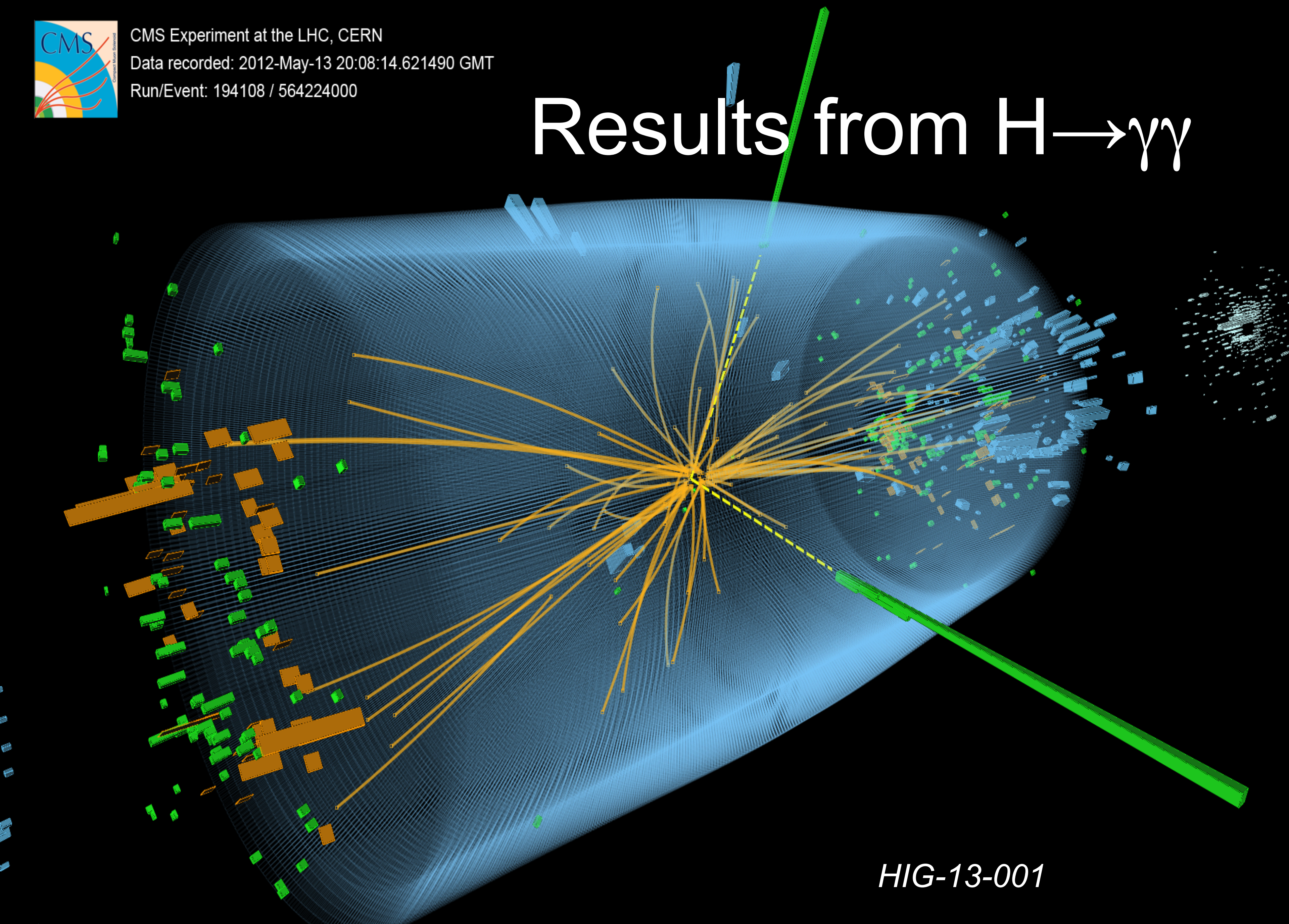


p-value Expected: 7.1 σ

Observed: 6.7 σ

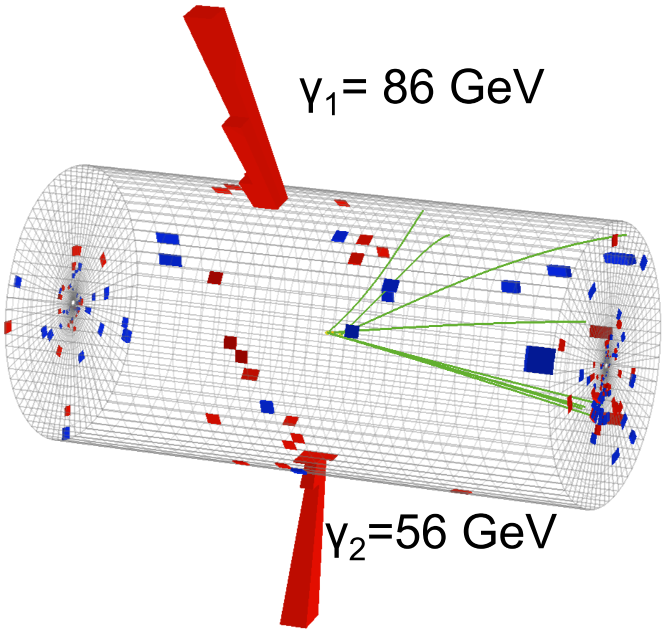
$\sigma/\sigma SM$ (m_H=125.7 GeV) = 0.92 ± 0.28

Results from H→γγ



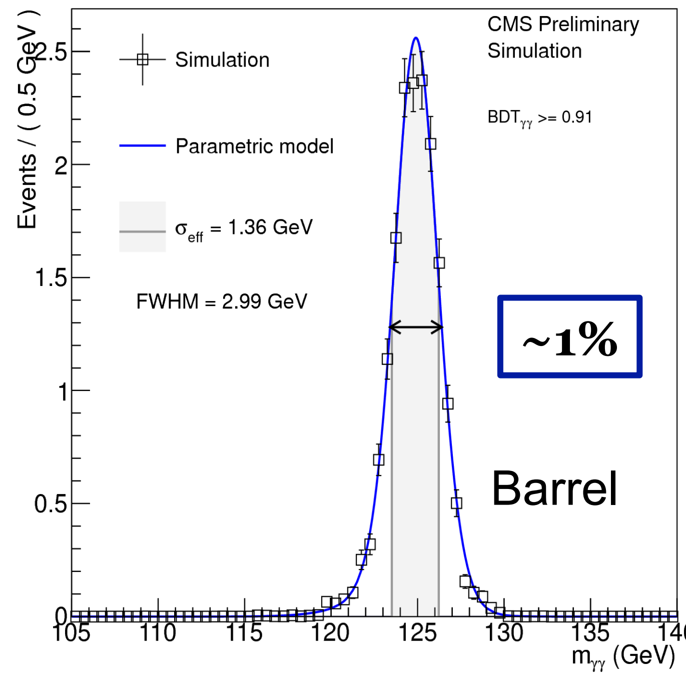
HIG-13-001

$H \rightarrow \gamma\gamma$



Signature:

- Two energetic and isolated photons
- Narrow mass peak on top of a large steeply falling background

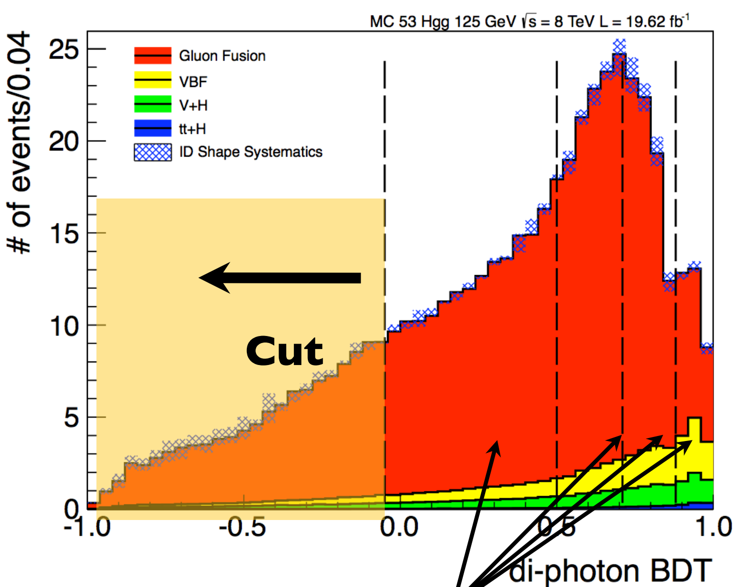


Relevant aspects:

- Photon identification/ background rejection
- Di-photon mass resolution
- Background estimation
- Primary vertex determination (pile-up!)

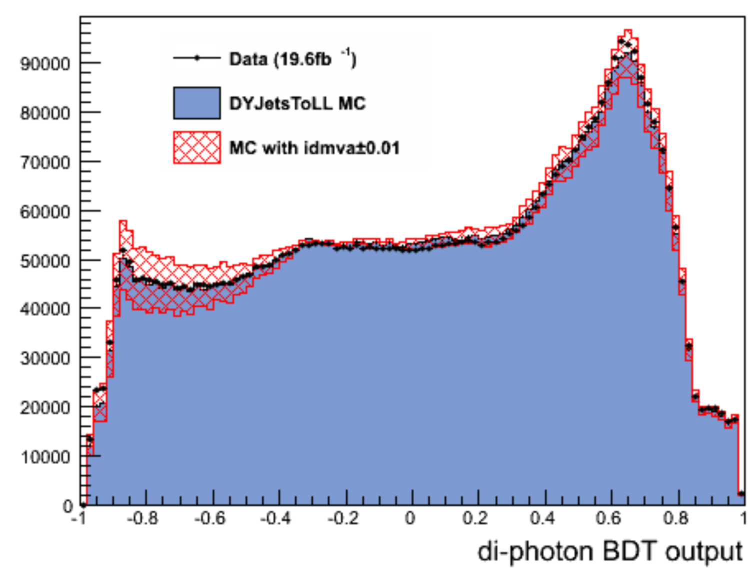
H→γγ analysis

- Two inclusive analyses:
  - MVA: photons selected with a BDT. Variables in the BDT: photon kinematics, photon ID MVA score (shower shape, isolation), di-photon mass resolution. 4 MVA categories with different S/B
  - Cut-based: photons selected with cuts. 4 categories based on: γ in Barrel/Endcap, (un)converted γ. Each category has different mass resolution and S/B
- 3 VH channels (e, μ and MET tag) + VBF (2 dijet categories)



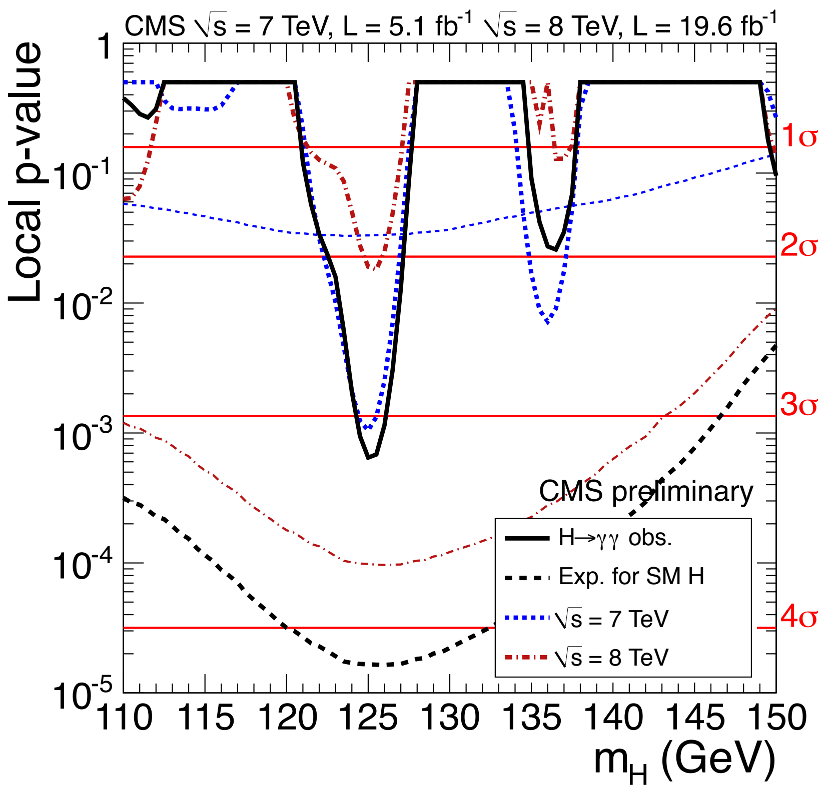
MVA event categories

Output of the MVA validated using Z→ee (where e are reconstructed as γ)



H→γγ: results (p-values)

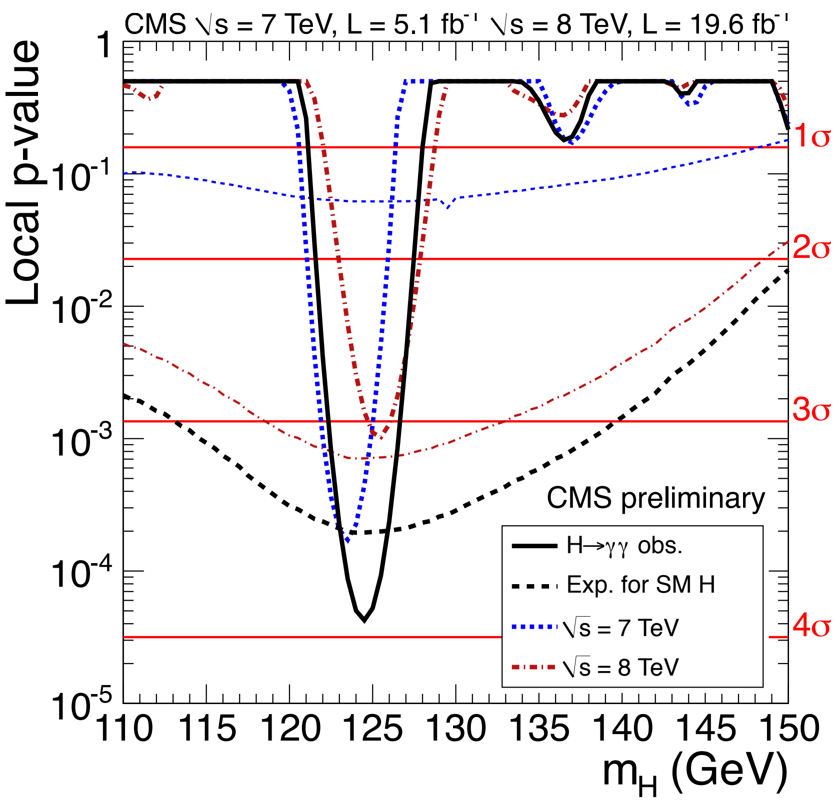
MVA



Significance at 125.0 GeV:

3.2 σ (4.2 exp.)

Cut-based



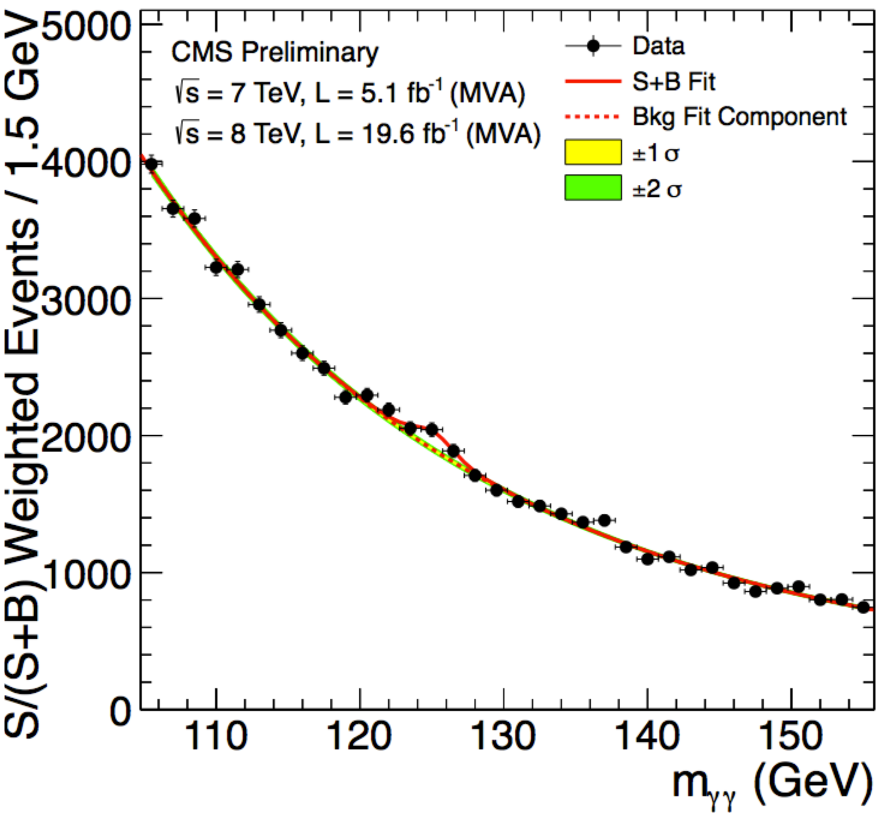
Significance at 124.5 GeV:

3.9 σ (3.5 exp.)

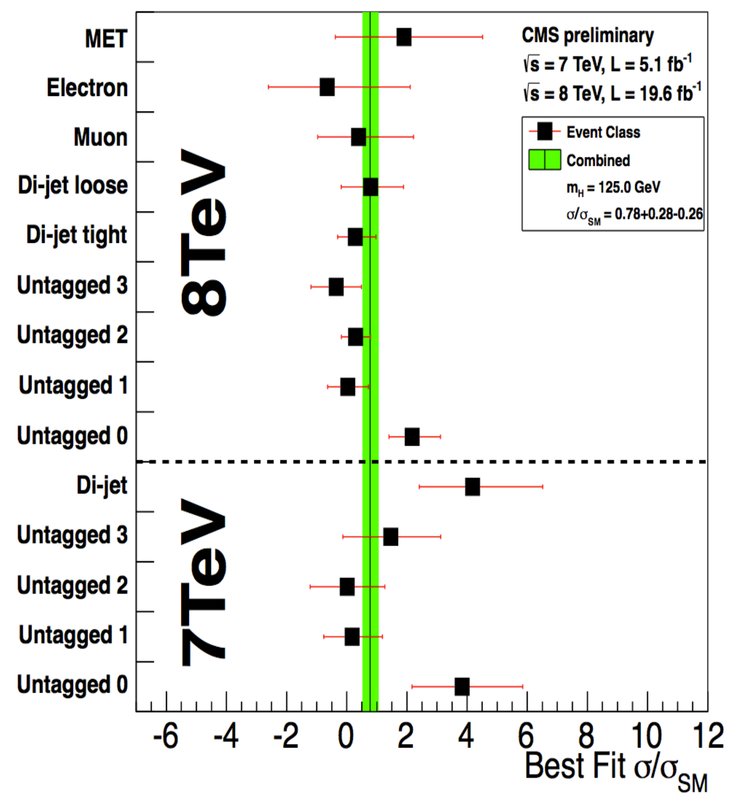
New data, new analysis: Significance decreased compared to the published results

H→γγ: combined mass plot

MVA



MVA

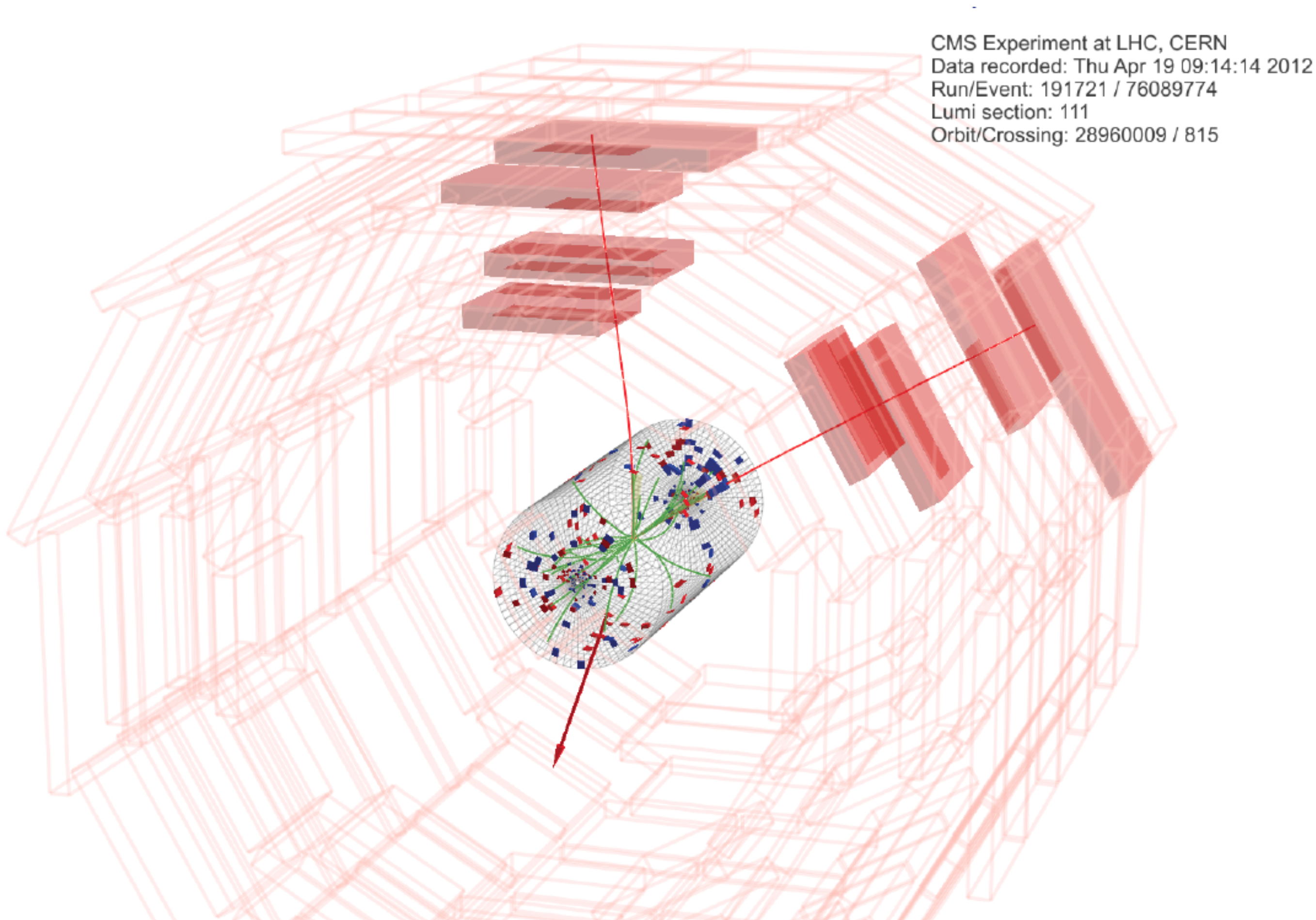


Each event category is **weighted by S/(S+B)** only for visualization purposes

7+8 TeV:

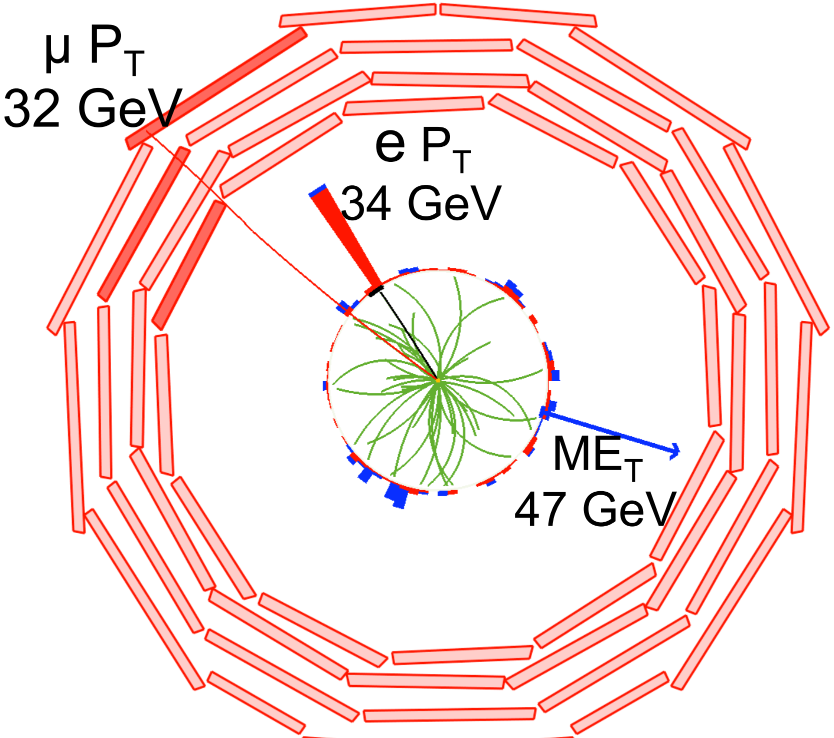
σ/σ_{SM} at 125.0 GeV = **0.78** $^{+0.28}_{-0.26}$

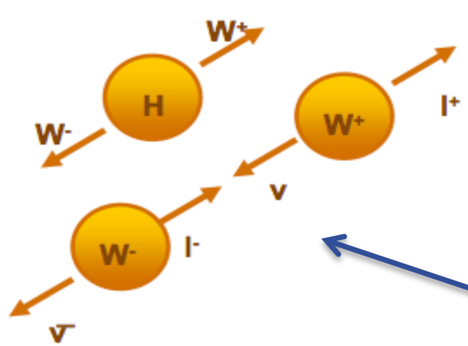
$H \rightarrow WW \rightarrow l\nu l\nu$



HIG-13-003

$H \to WW \to l\nu l\nu$





- Channel with very high σ.BR
- Clean signature:
  - 2 isolated, high p_T leptons with small opening angle
  - High Missing E_T
  - Analysis performed on exclusive jet multiplicities (0, 1, 2-jet bins)
  - Different Flavour, Same Flavour leptons
- Discriminant Variables:
  - p_T^l, M_{ll}, M_T, $\Delta\phi$
  - VBF selections for the 2-jets case
- Cut-based and Shape analysis in (M_{ll}-M_T) plane

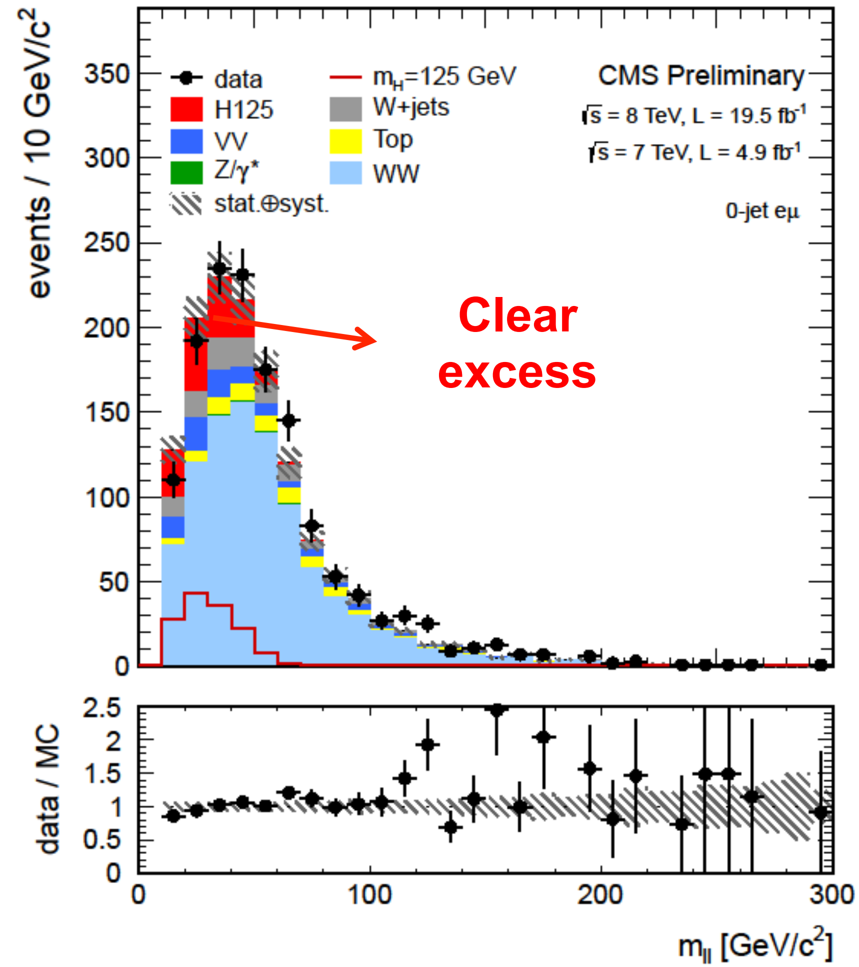
good sensitivity to spin
small opening angle between leptons

H →WW→lνlν: backgrounds

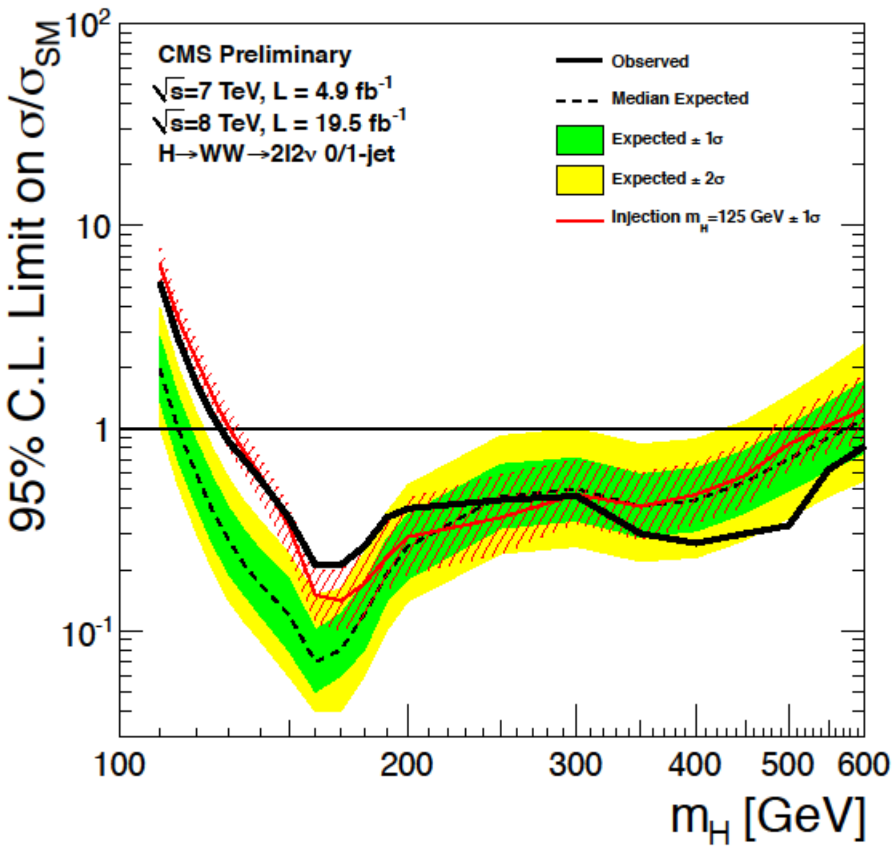
All the backgrounds are estimated from data in “control regions”

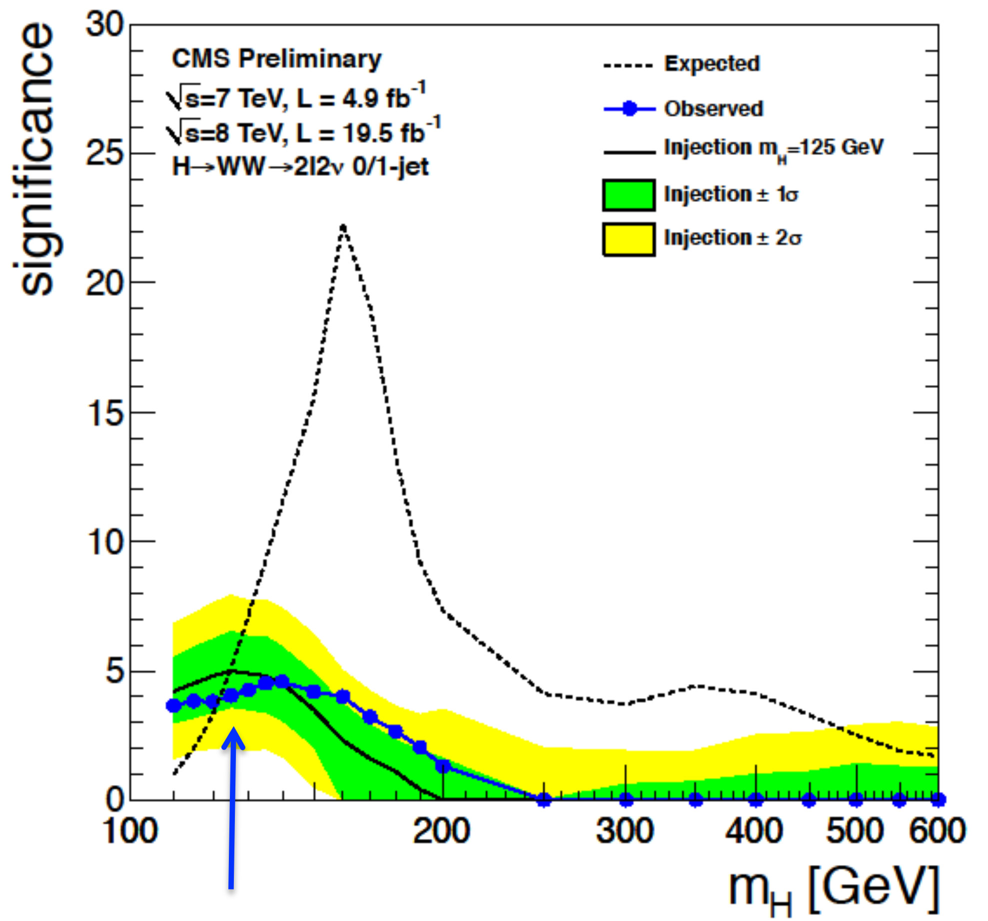
- **Drell –Yan:** Suppressed by M_{ll} and Missing E_T cuts
- **W+jets (with one jet faking a lepton):** lepton ID is important
- **Top (tt and single top):** b-tag veto (or additional soft muon)
- **WW:** M(ll), M_T and $\Delta\phi$

m_{ll} (0 jet, DF)



H →WW→lνlν: results



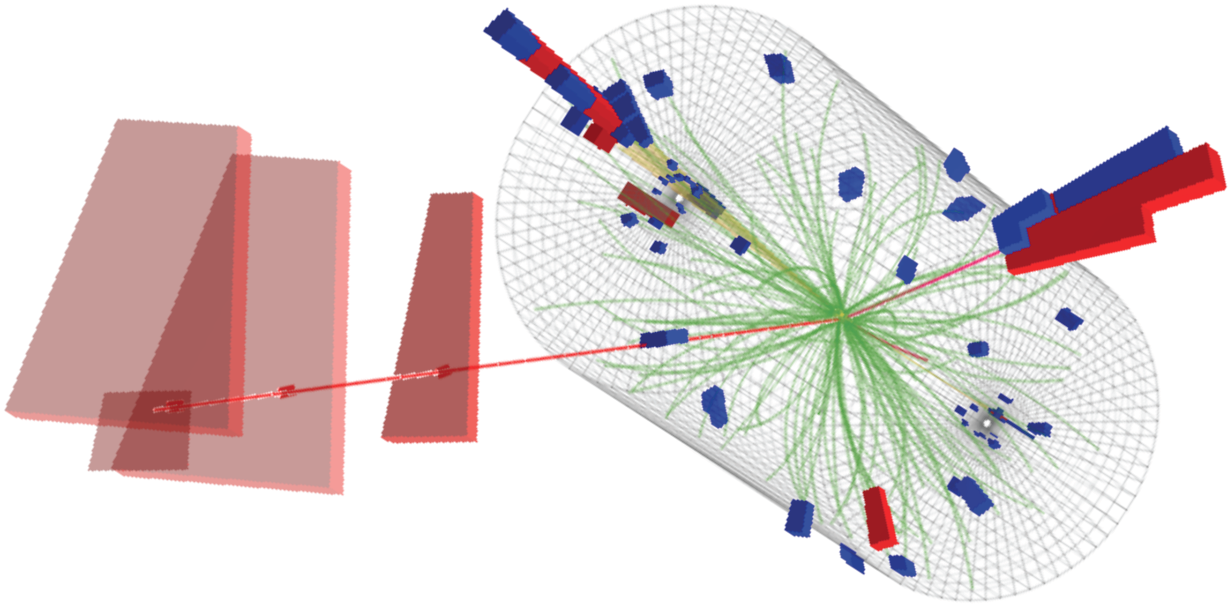


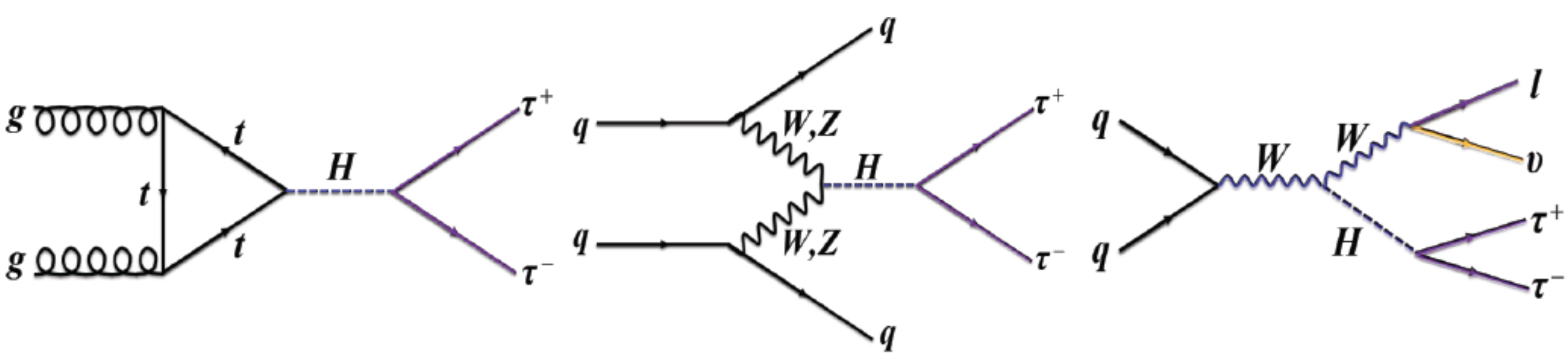
Large excess at low mass compatible with the expected Higgs signal

σ/σ_{SM} at 125 GeV = 0.76 ± 0.21

Significance at 125 GeV: 4.0 σ (5.1 expected)

H → ττ



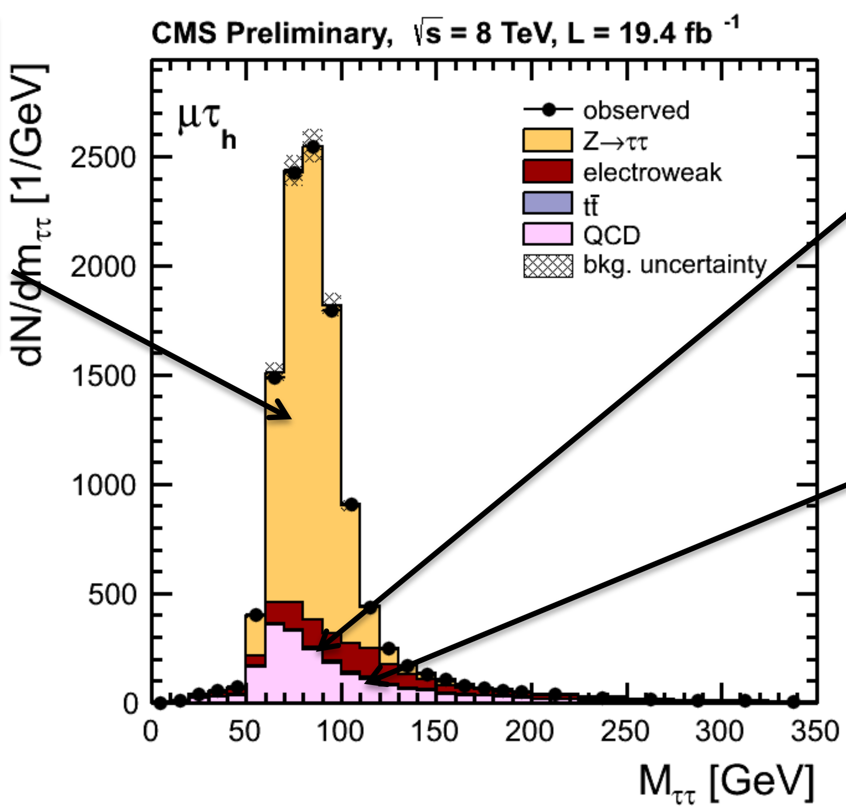


HIG-12-053

H → ττ analysis

- Reconstructed τ decays: e, μ, τ_{had}
- Categorize events based on number of jets and $\tau\, p_T$ (VH, VBF)
- Template fit to $m_{\tau\tau}$ shape

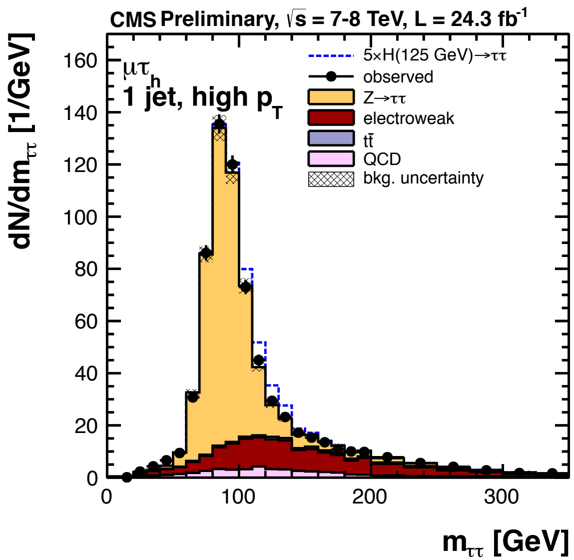
Z→ττ Embedding:
$Z\rightarrow\mu\mu$ data, replace μ with simulated τ decay
Normalization from $Z\rightarrow\mu\mu$ data
Syst: 5%

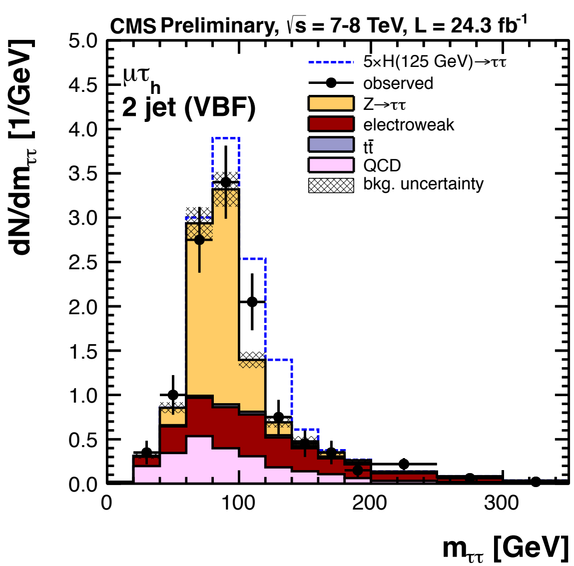


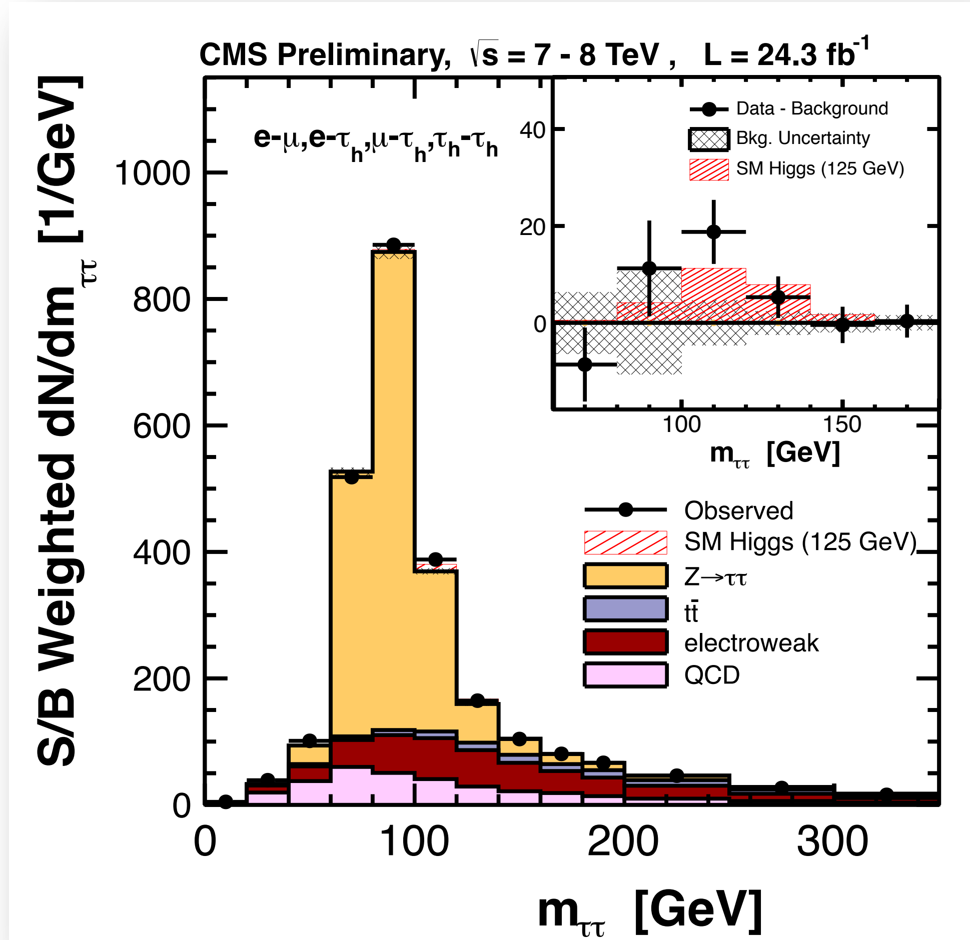
W+jets
Shape from simulation
Normalization from control region
Syst: 10-20%

QCD
SS data, corrected for SS/OS ratio
Syst: 10%

ττ mass spectrum

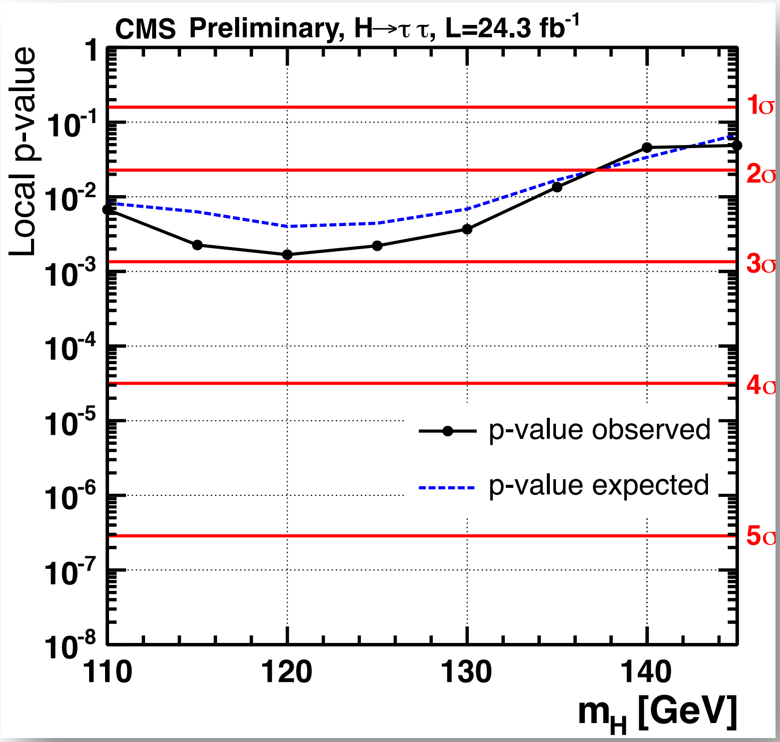


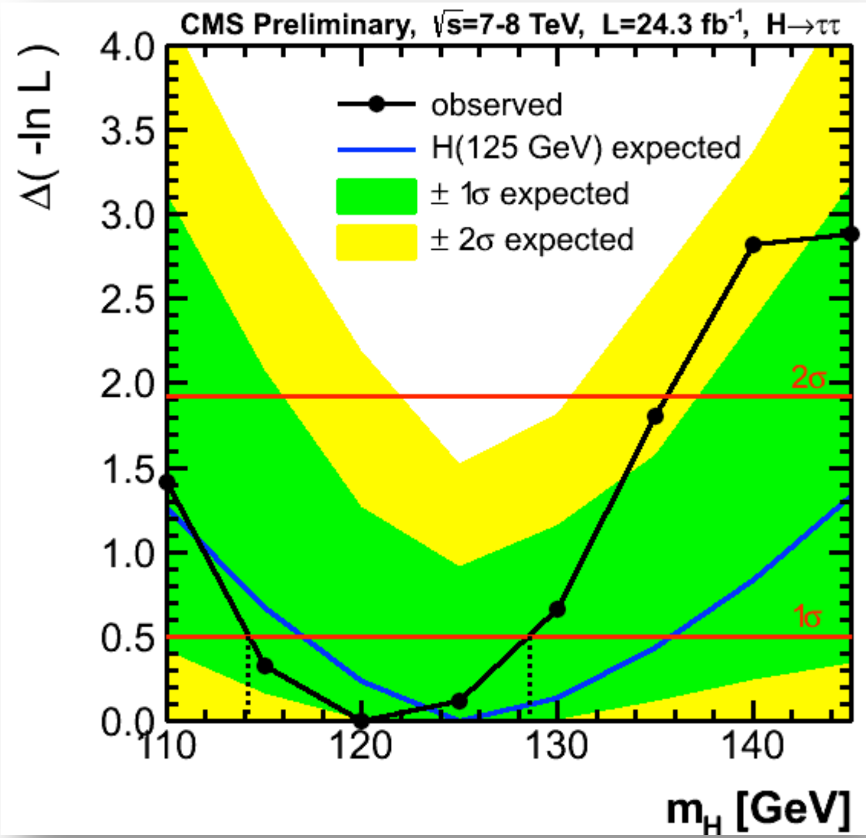




Combine the sensitive categories of all channels with a S/B weight

$H \rightarrow \tau\tau$ results





Significance:

2.93 σ @ mH = 120 GeV

2.85 σ @ mH = 125 GeV

Signal strength:

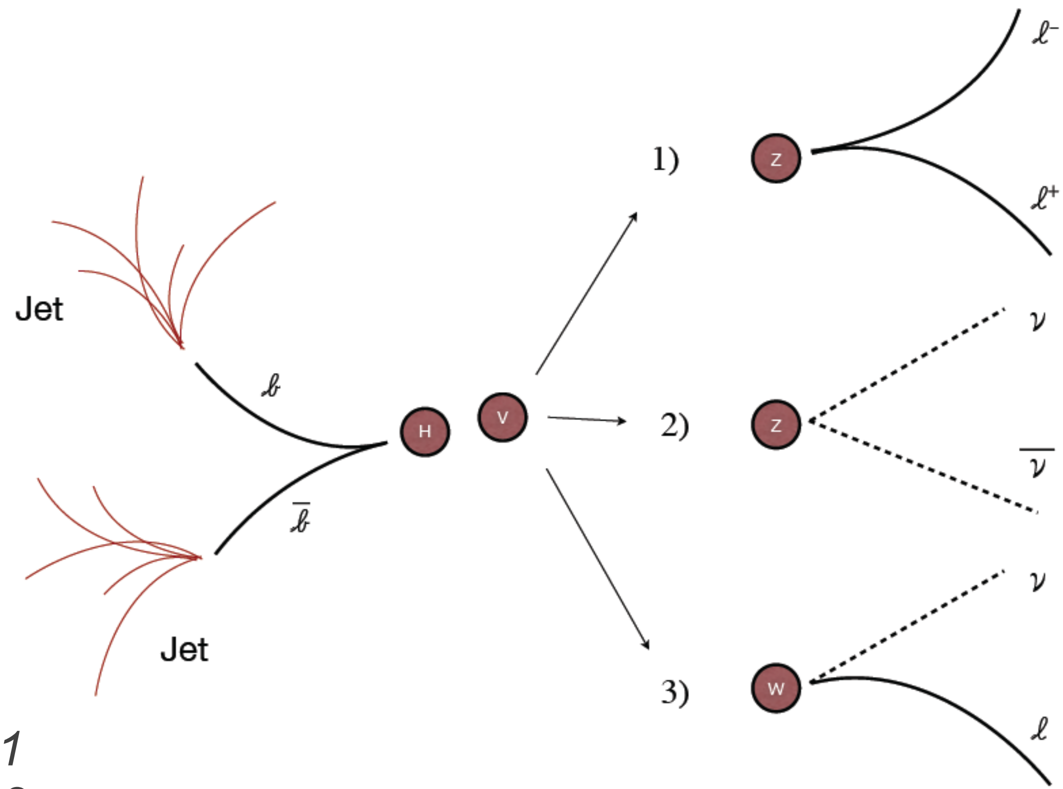
μ = 1.1 ± 0.4

All ττ channels combined:

$m_H = 120^{+9}_{-7}$ (stat+syst) GeV

VH →bb + X

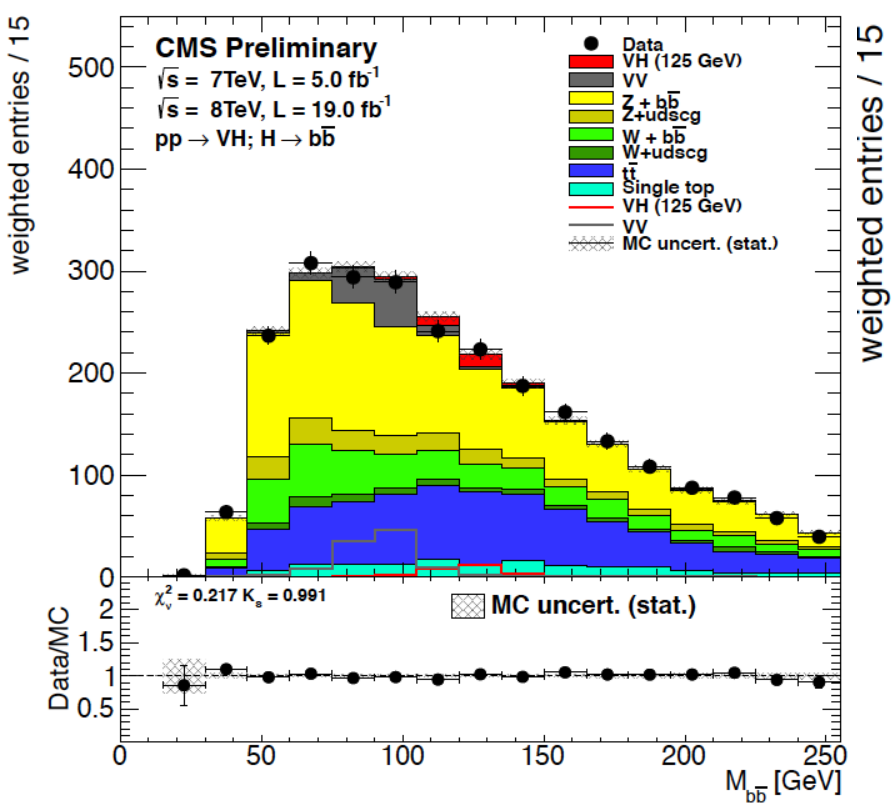
- 2 central b jets plus V (W, Z) decaying into leptons
- Background from V+jets, VV, top+X
- Improved dijet mass resolution
- BDT shape analysis: jets and V kinematics, b tagging



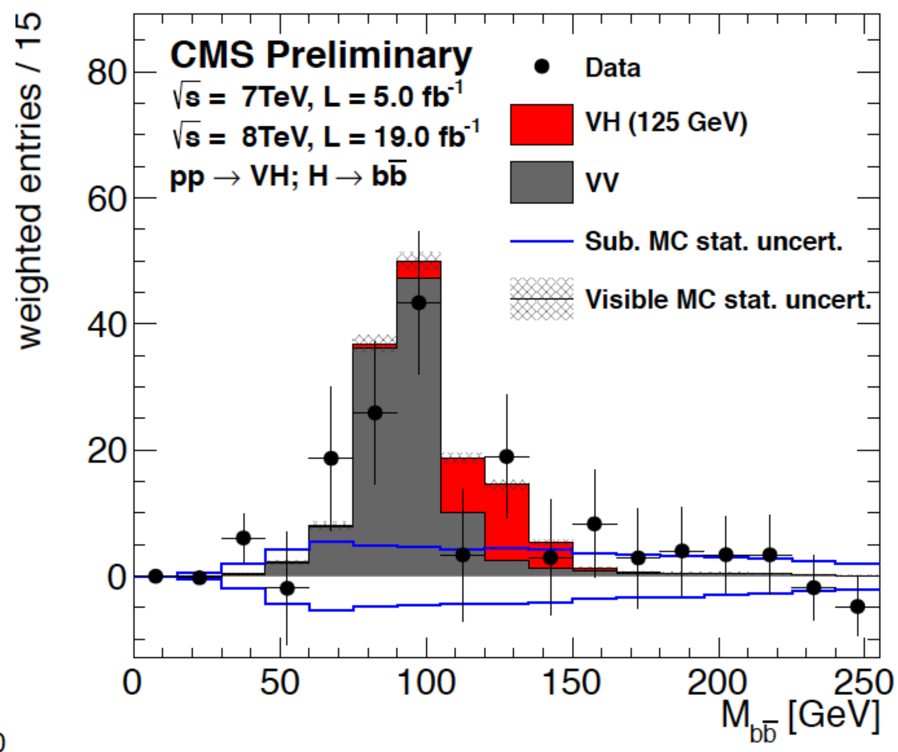
HIG-13-011
HIG-13-012

Dijet mass distributions

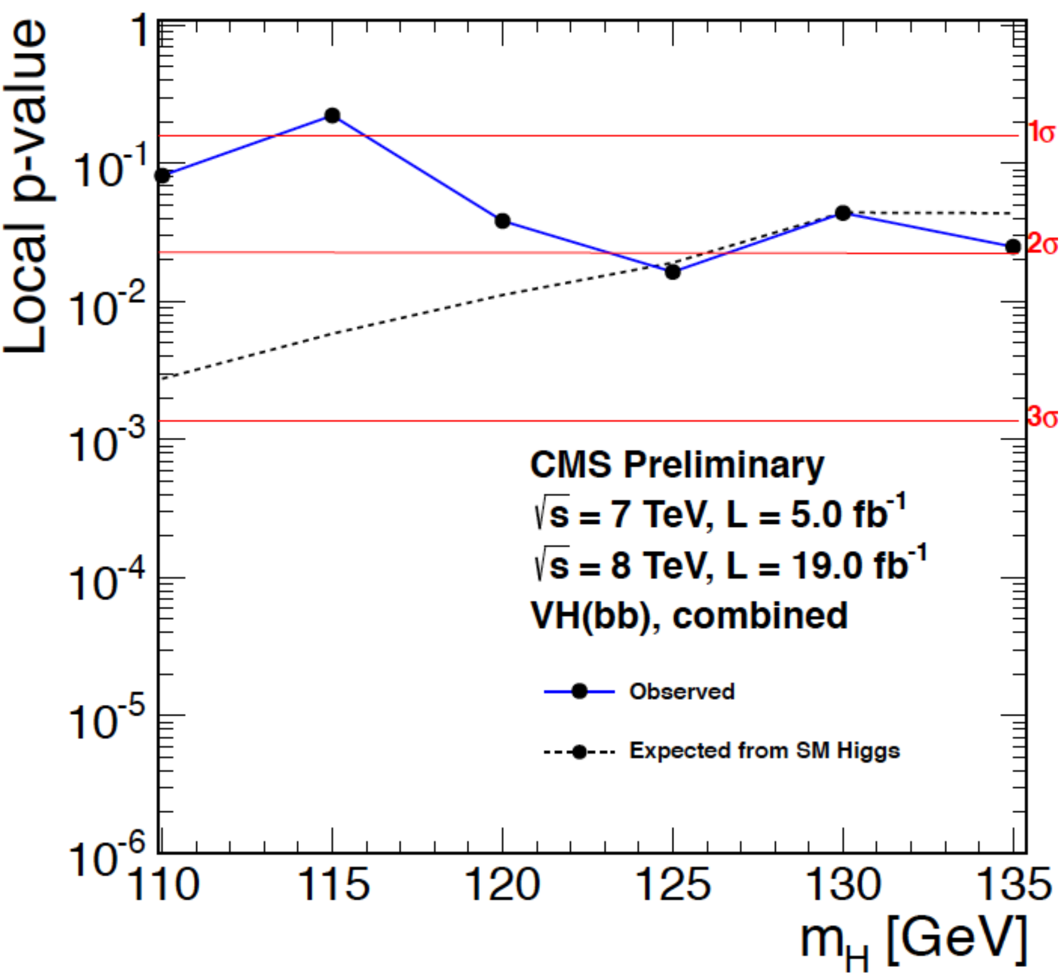
All channels combined

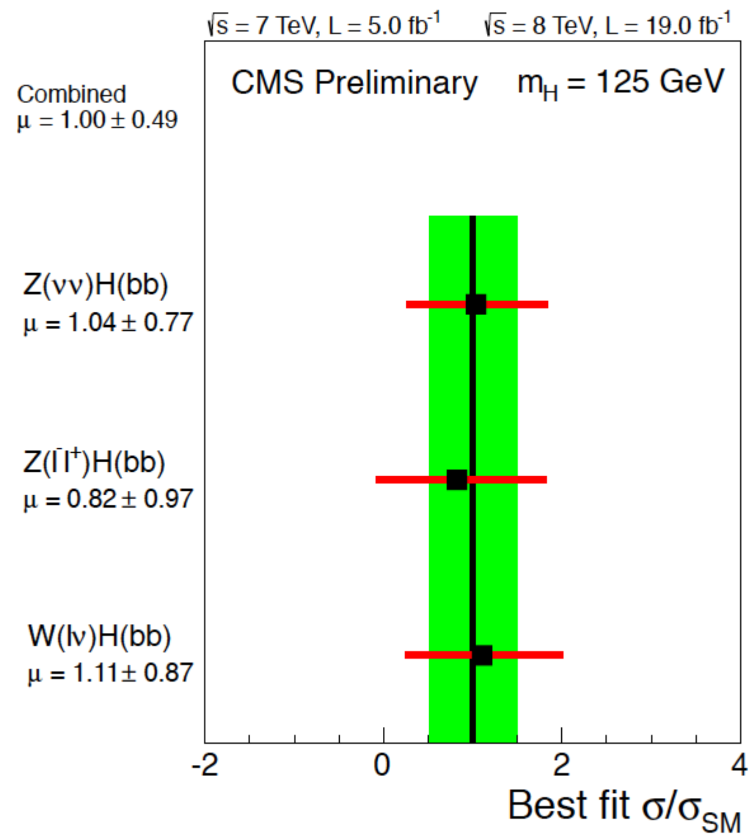


All backgrounds, except VV, subtracted



VH →bb results





At 125 GeV:

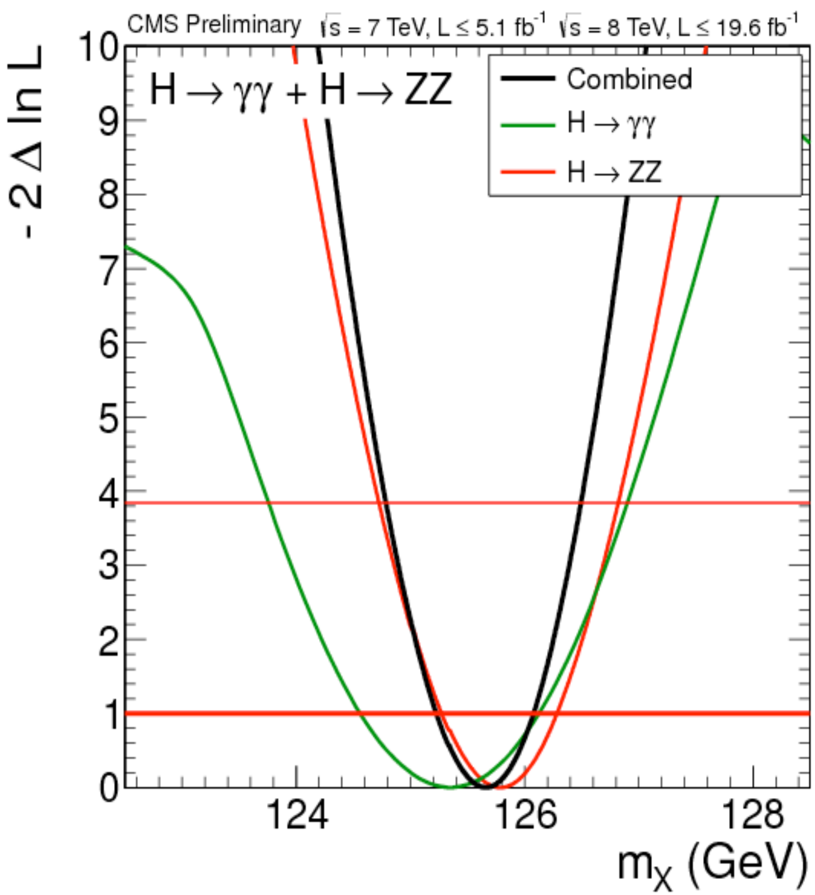
Significance= **2.1σ**

μ = 1.0±0.5

Higgs properties

HIG-13-005

H mass



H →ZZ→4l:

Mass estimation with m_{4l}, KD and $\sigma(m_{4l})$
Very small systematics due the very good control of the leptons scale and resolution:

m_H **= 125.8 ± 0.5 (stat.) ±0.2 (syst.) GeV**

H →γγ:

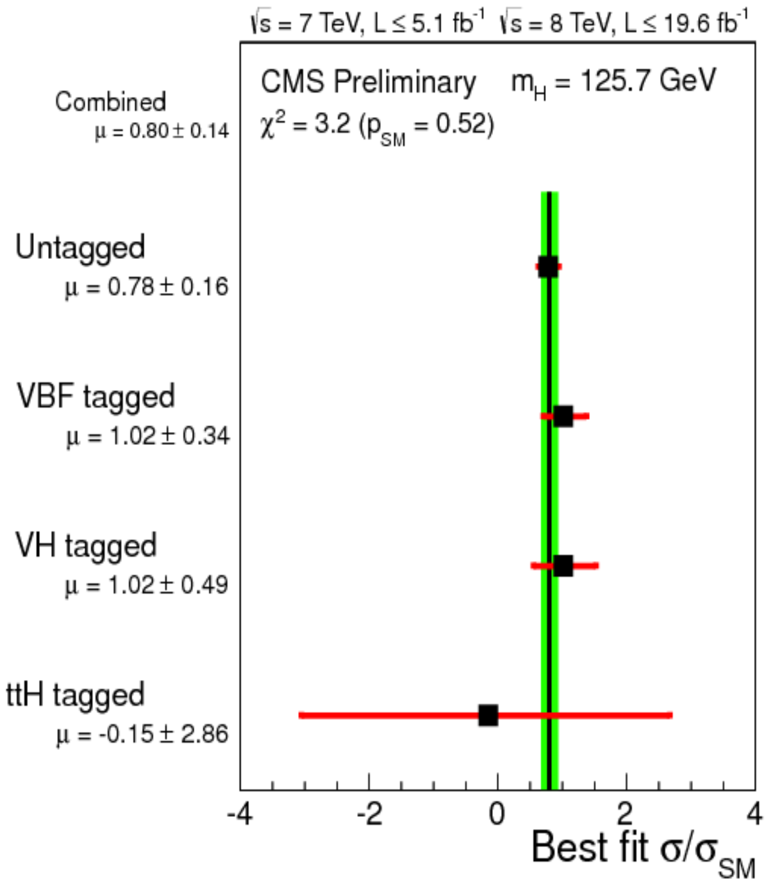
Systematics on the extrapolation from the Z→ee to H→γγ (0.25% from e to γ, 0.4% from Z to H):

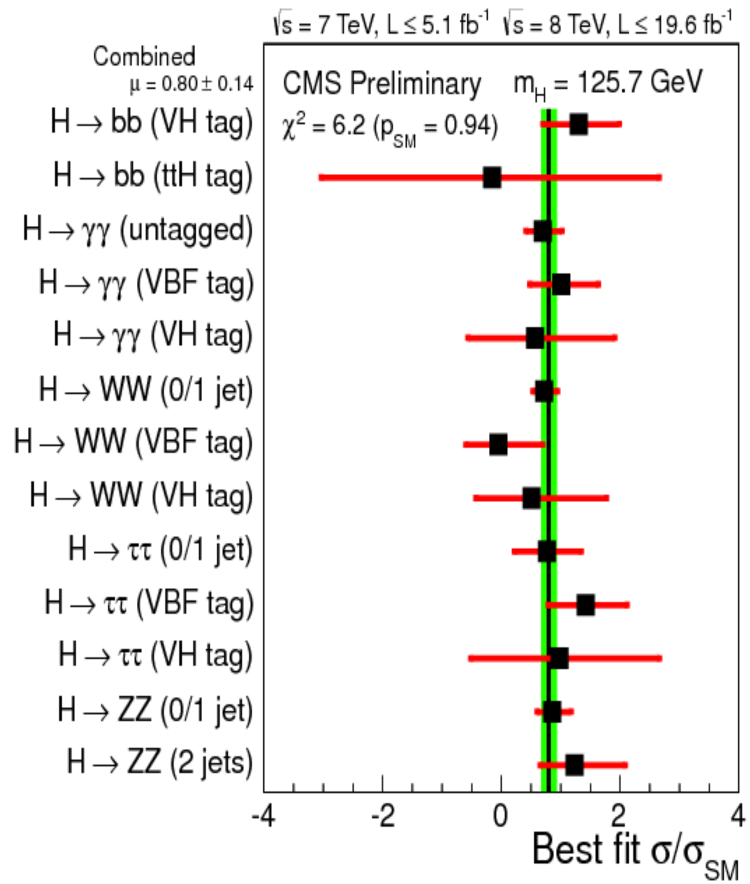
m_H **= 125.4 ± 0.5 (stat.) ±0.6 (syst.) GeV**

$$m_X = 125.7 \pm 0.3^{(stat)} \pm 0.3^{(syst)}\ \text{GeV}$$
$$= 125.7 \pm 0.4\ \text{GeV}$$

Consistency of signal with SM

μ signal strength: ration of σ.BR measurement and SM prediction



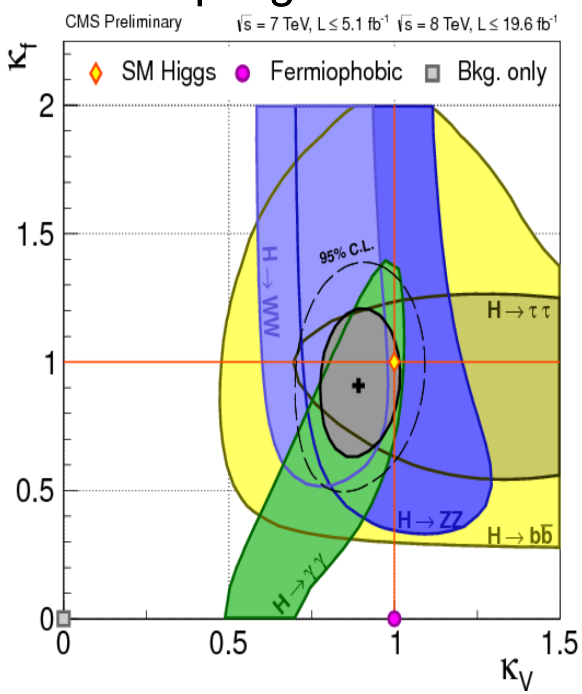


$\boxed{\mu=0.80\pm0.14}$

Couplings to bosons and fermions

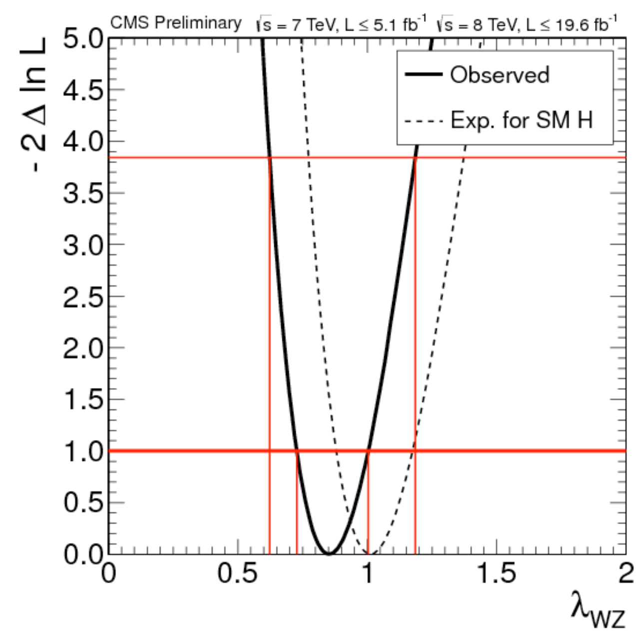
- LHC XS WG benchmark models:
  - Fermionic vs bosonic couplings modifiers: κ_V κ_f
  - Search for asymmetries: λ_{WZ}, λ_{du}, λ_{lq}
  - Search for new physics in loops: κ_g κ_γ BR_{BSM}

Couplings to V and F



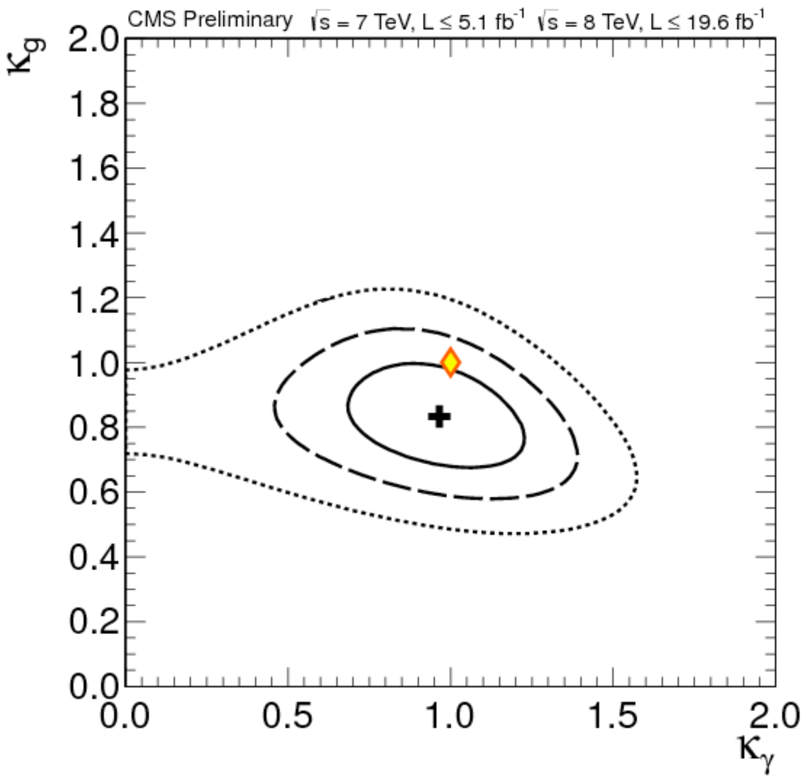
K_V [0.81, 0.97] @ 68% CL
K_F [0.71, 1.11] @ 68% CL

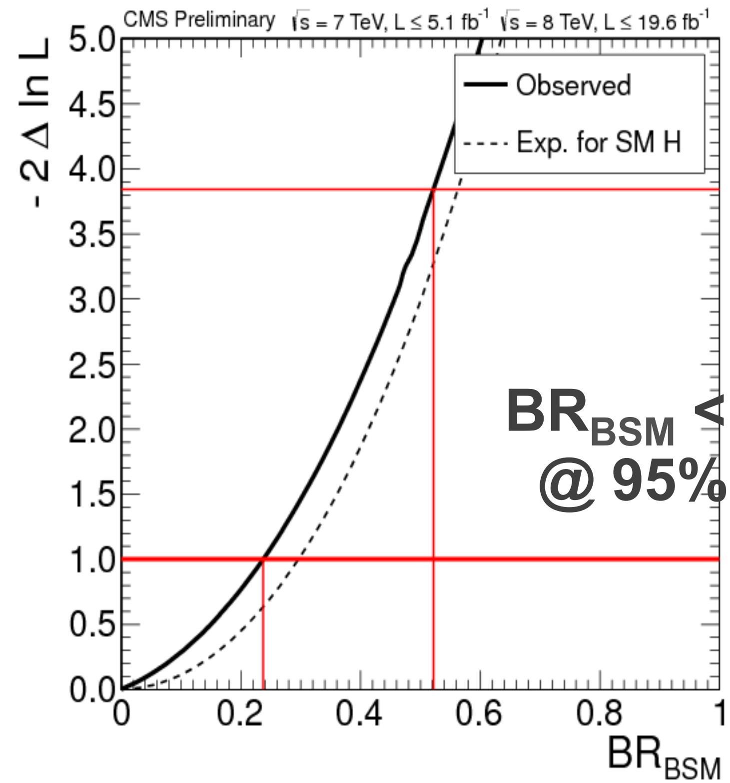
Custodial symmetry



λ_{WZ} [0.73,1.00] @ 68% CL

Couplings to gluons and photons





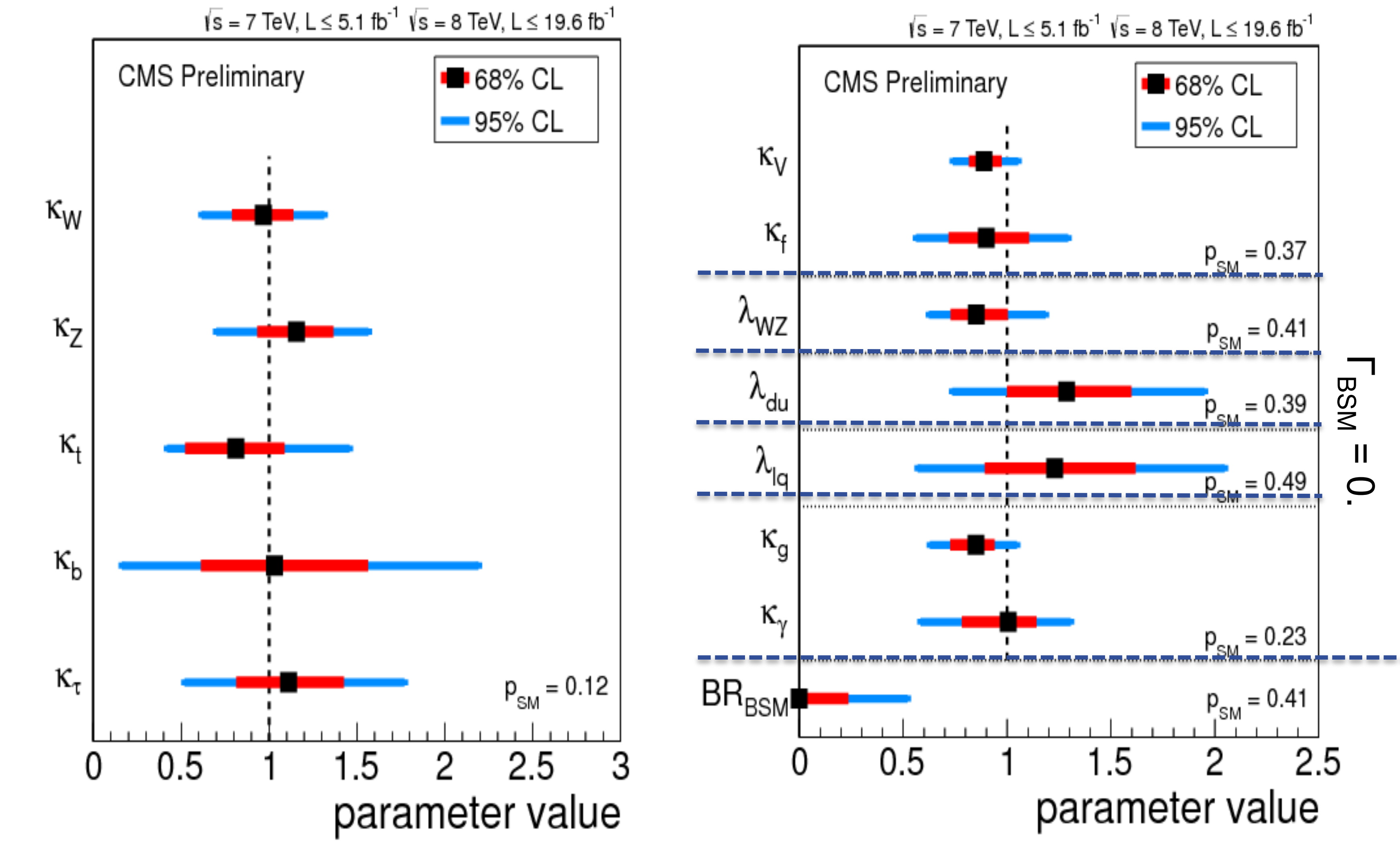
BR_{BSM} < 0.52
@ 95% CL

Effective couplings to gluons and photons.

Γ_{BSM} = 0.

Loop-induced couplings free (κ_γ , κ_g profiled).

Summary of couplings

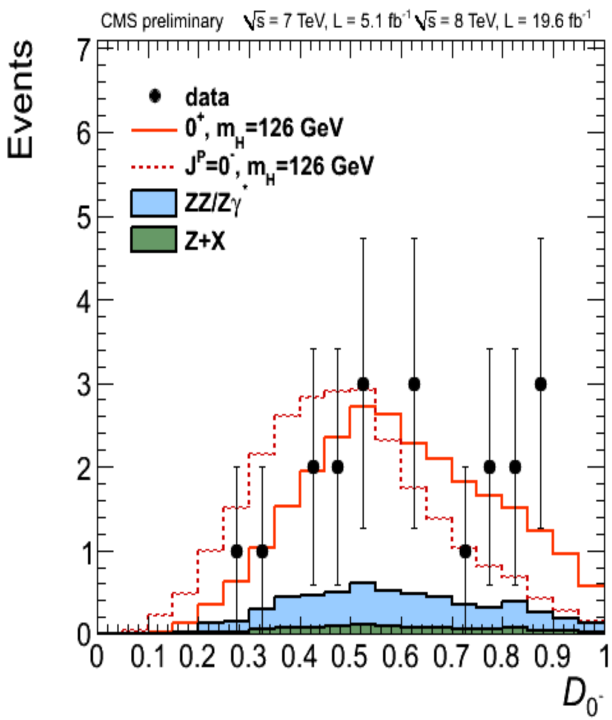


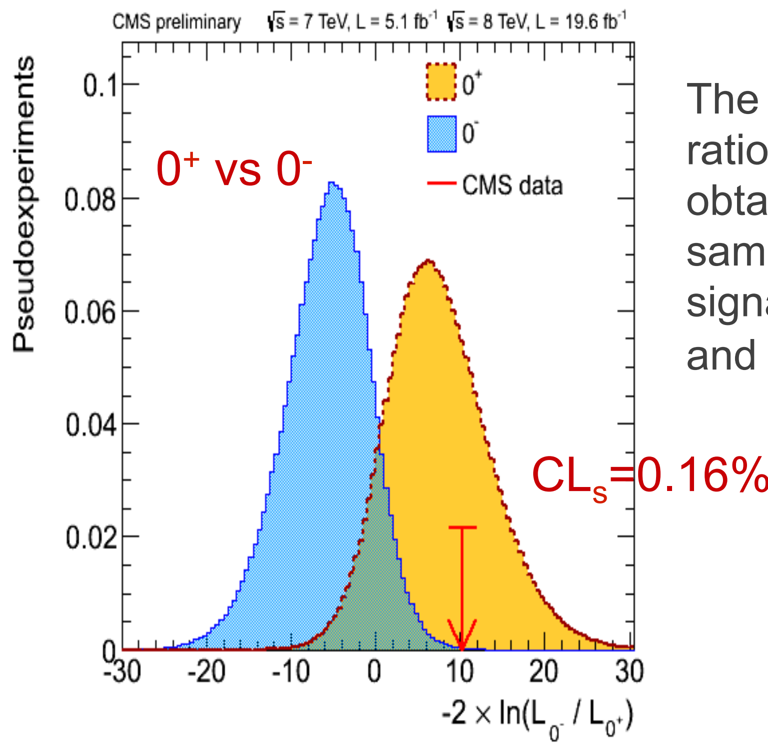
$\Gamma_{BSM} = 0.$

Spin-Parity: 0^+ vs 0^-

- Kinematic Discriminant : $D_{JP}=P_{SM}/(P_{SM}+P_{JP})$
- Second observable: $D_{bkg} = P_{sig}/(P_{sig} + P_{bkg})$
  - P_{bkg} and P_{sig} include the m_{4l} parameterizations
- Likelihood fit of events to 2D distributions (D_{JP}, D_{bkg})

$H \rightarrow ZZ^{(*)} \rightarrow 4l$





The distribution of the likelihood ratio $q = -2\ln(L_{JP}/L_{SM})$ is obtained with generated samples of background and signal of seven types (SM 0^+ and six J^P) for m_H=126 GeV.

More J^P hypotheses tested

J^P	CL_s
0^-	0.16%
0^+_h	8.1%
2^+_{mgg}	1.5%
$2^+_{mq\bar{q}}$	<0.1%
1^-	<0.1%
1^+	<0.1%

The data disfavours 0^- (pseudoscalar) hypothesis with a CLs value of 0.16%

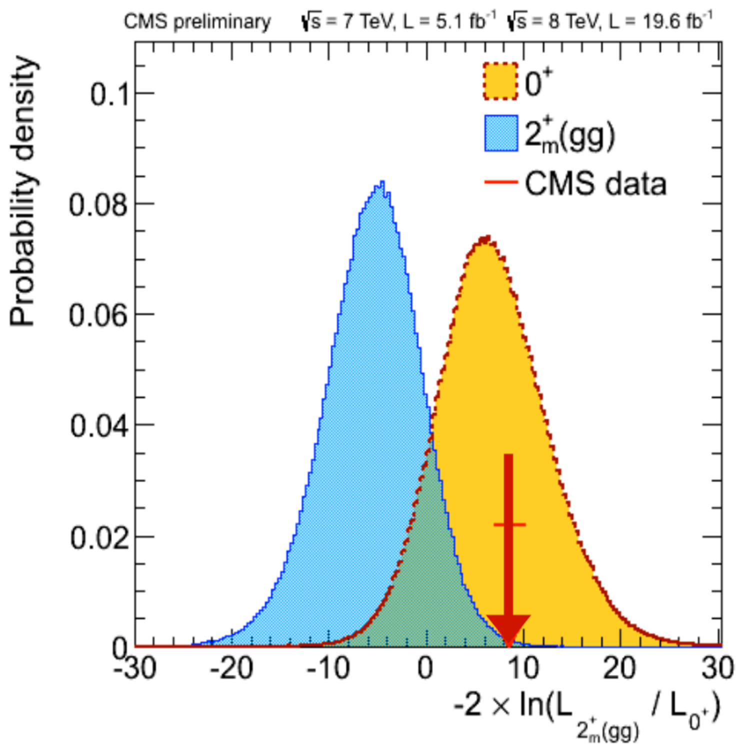
Spin-Parity: 0^+ vs 2^+

CLs values for 2^+_m(gg):

Observed results at measured μ

ZZ	WW	Comb
1.4%	14%	0.6%

- WW: observed results weaker than expected due to best fit $\mu < 1$
- ZZ: observed better than expected due to a fluctuation

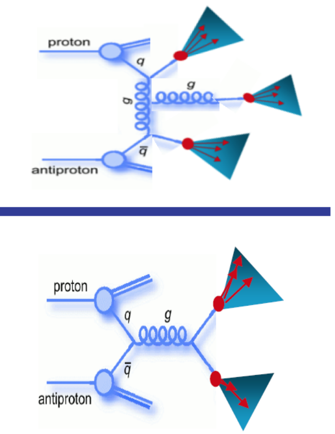


The data disfavours 2^+_m(gg) hypothesis with a CLs value of 0.6%

The observations are compatible with SM Higgs expectation (scalar)

Jets, vector bosons, top

3-jet to 2-jet cross section

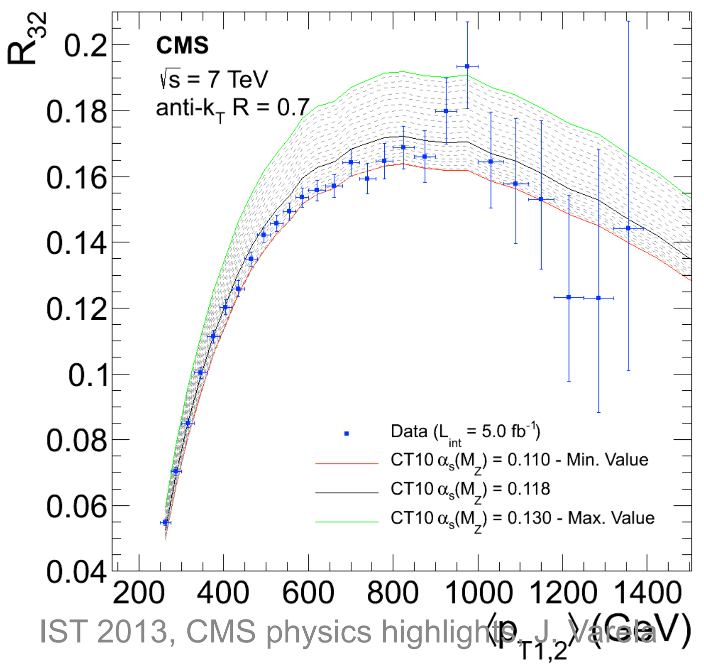


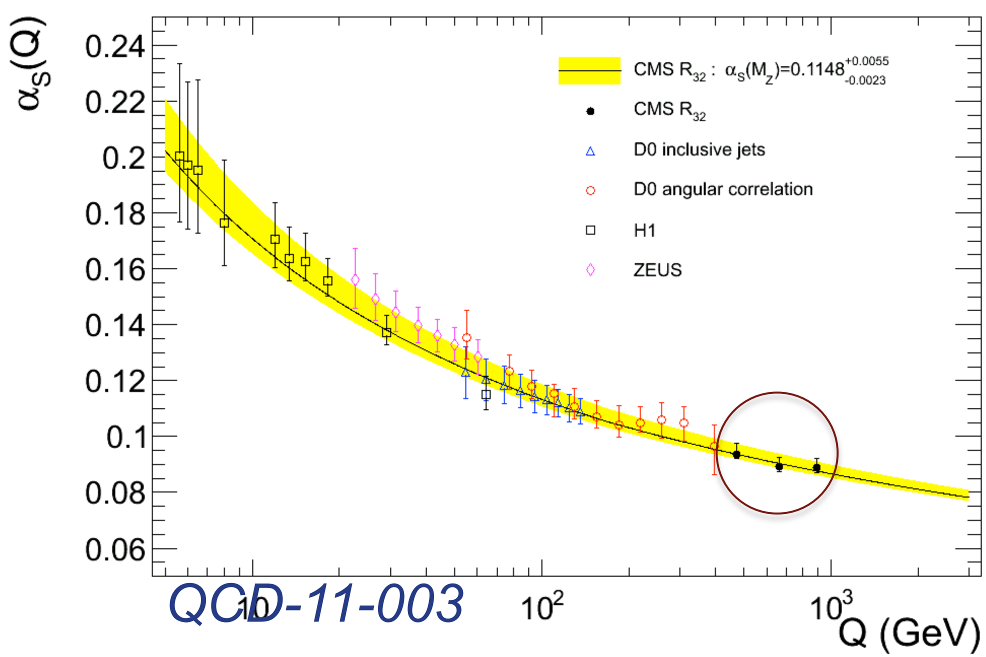
$\Leftrightarrow$ α_s

First determination of α_s at momentum scales > 0.4 TeV

- Comparing the ratio in the range 0.42< $\langle p_{T1,2} \rangle$ <1.39 TeV to the predictions of perturbative QCD at next-to-leading order
- Measurement dominated by TH uncertainty: PDF & scale

$$\alpha_s(M_Z) = 0.1148 \pm 0.0014(\text{exp.}) \pm 0.0018(\text{PDF})^{+0.0050}_{-0.0000}(\text{scale})$$



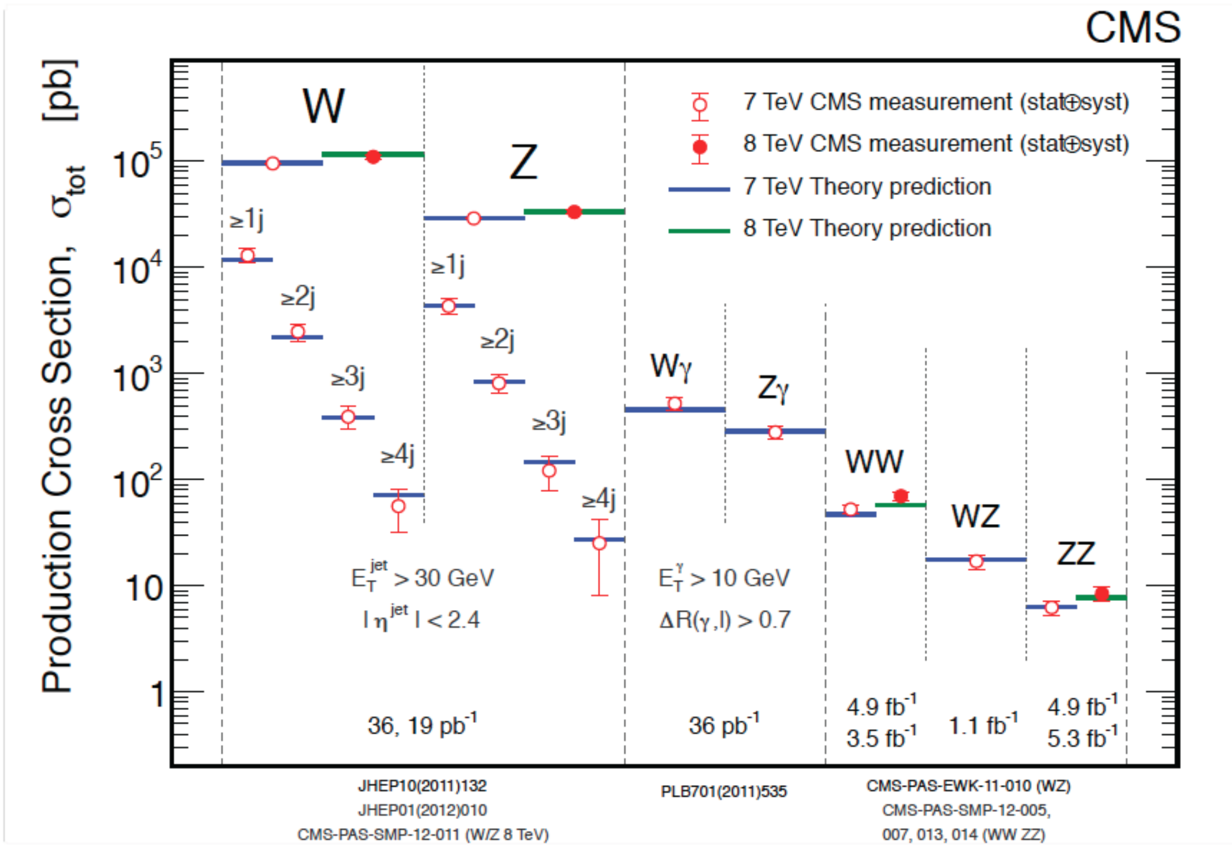


QCD-11-003

Vector bosons

W, Z, WW, and ZZ cross sections at 8 TeV

(Special Low PU runs used for W,Z at 8 TeV)



SMP-12-011
SMP-12-013
SMP-12-014

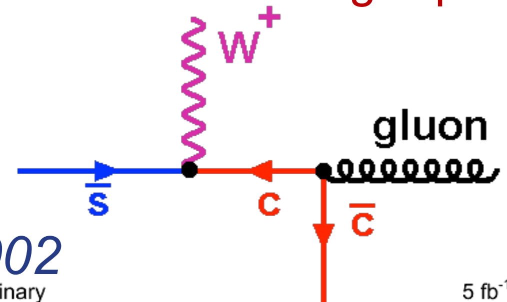
Measured σ (ZZ) = 8.4 ± 1.3 pb
SM (NLO) σ (ZZ) = 7.7 ± 0.4 pb

Measured σ (WW) =69.9 ± 7.0 pb
SM (NLO) σ (WW) = 57.3 ± 2.0 pb

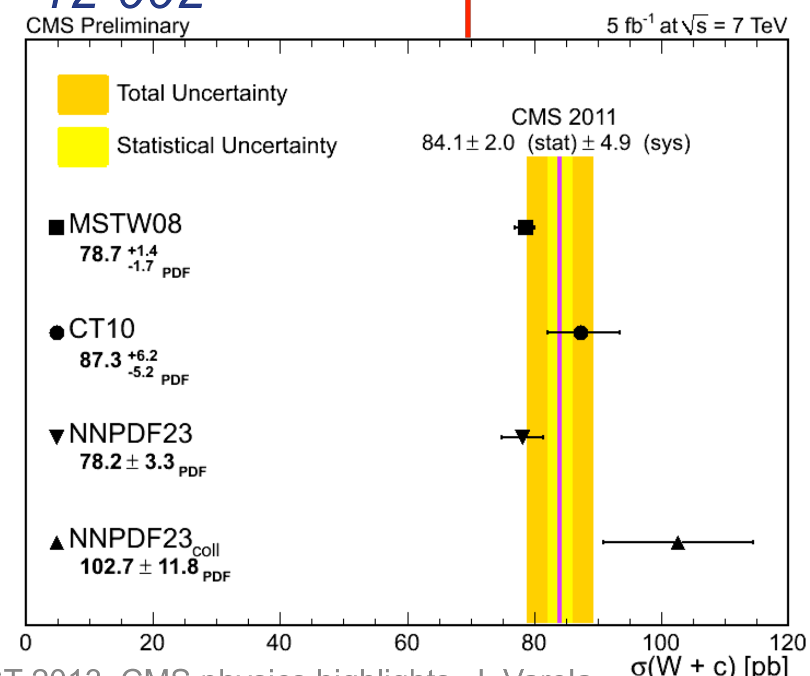
V + heavy quarks

W+c production with exclusive charm tagging via full reconstruction of D±, D*, and semileptonic decays

Direct access to the strange-quark PDF



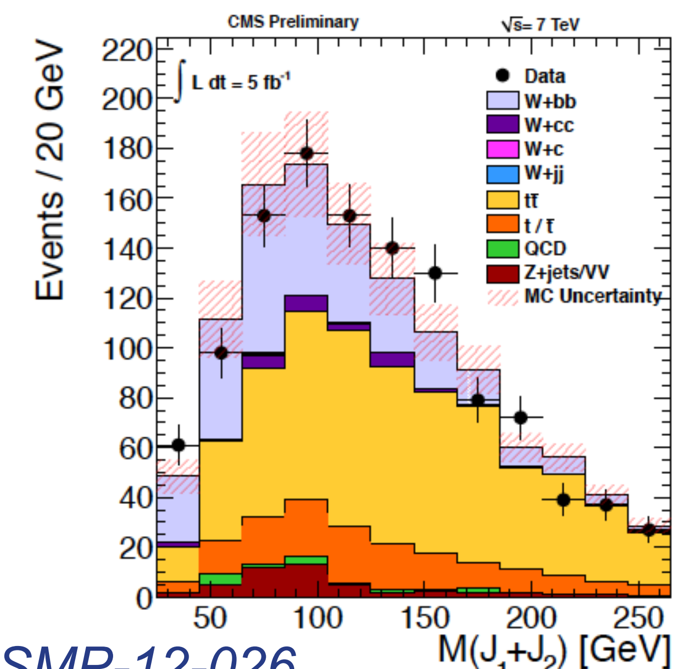
SMP-12-002



W+bb and Z+bb cross section measurements:

- σ x Br(W→$\mu\nu$) = 0.53 ± 0.12 pb @ 7 TeV ($p_T^{b,\mu}$ > 25 GeV), in good agreement with NLO prediction of 0.52 ± 0.03 pb
- σ x Br(Z→ll) = 0.36 ± 0.07 pb @ 7 TeV (p_T^{b} > 25 GeV)

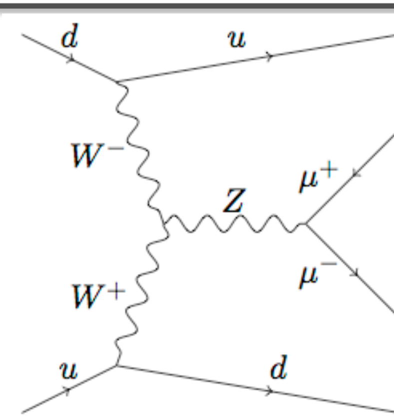
SMP-13-004



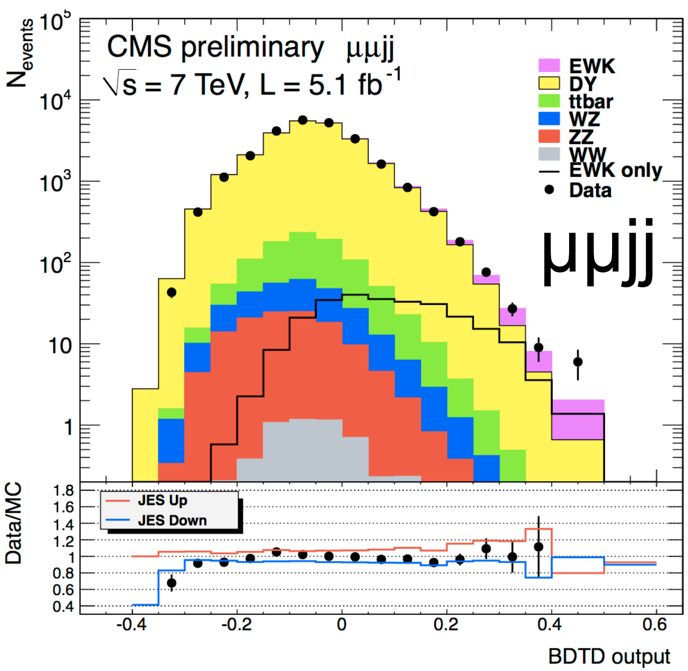
SMP-12-026

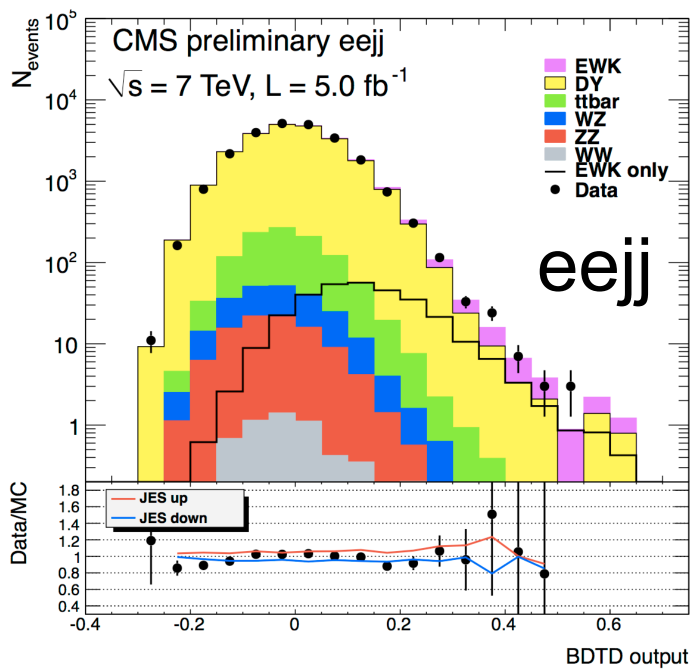
VBF Z production

- First-time ever observed !
- Benchmark for VBF Higgs searches
- Dominant background from standard DY production
  → BDT discriminant used to extract the signal



$$\sigma^{EWK}_{\text{meas},\,\mu\mu+ee} = 154 \pm 24(\text{stat.}) \pm 46(\text{exp.syst.}) \pm 27(\text{th.syst.}) \pm 3(\text{lumi.})\ \text{fb}$$





Agreement with NLO prediction (σ_{NLO}=166 fb, VBFNLO, CT10)

7 TeV

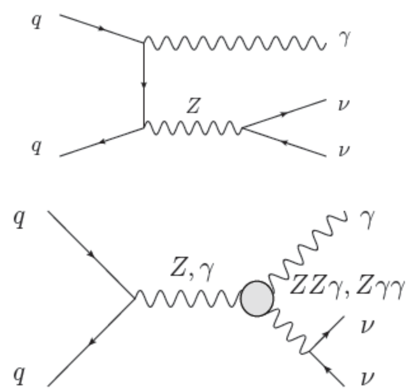
FSQ-12-019

Anomalous TGCs

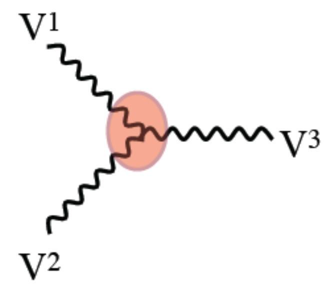
Z(νν)γ cross section:

σ = 21.3 ± 4.2 (stat.) ± 4.3 (syst.) ± 0.5 (lumi.) fb

In good agreement with the theoretical prediction of 21.9 ± 1.1 fb (BAUR).

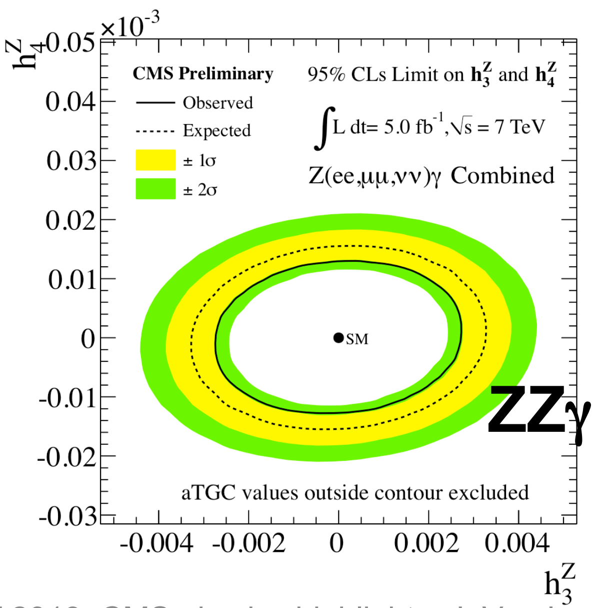


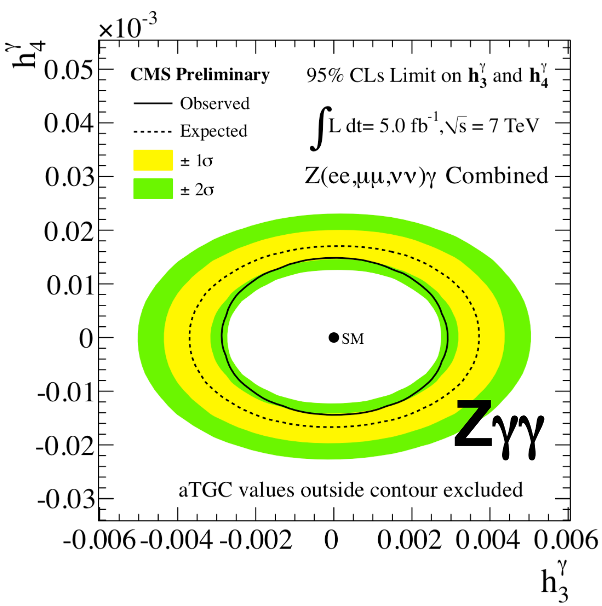
Forbidden in SM



aTGCs in CMS:
EWK-11-009 (Vγ),
SMP-12-015 (WW,WZ)
SMP-12-007 (ZZ),
SMP-12-020 (Zγ)

Z(ee, μμ, νν)γ combined:

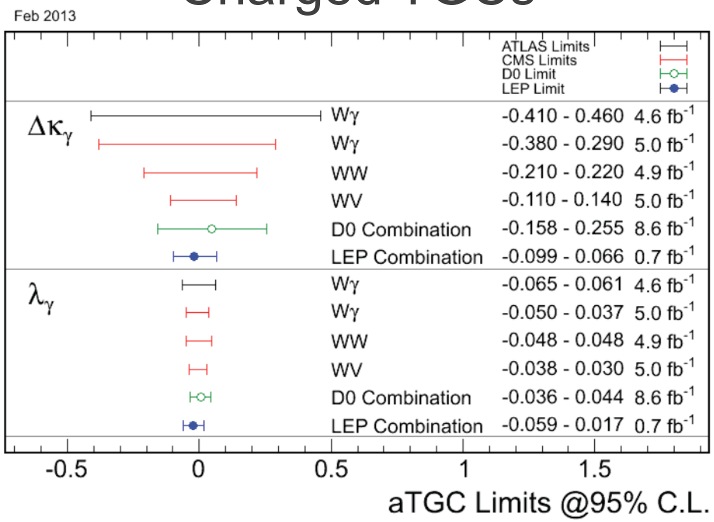




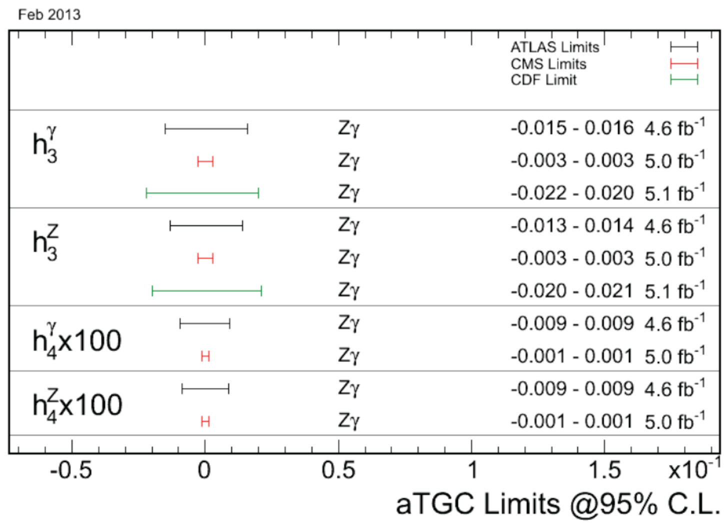
SMP-12-020

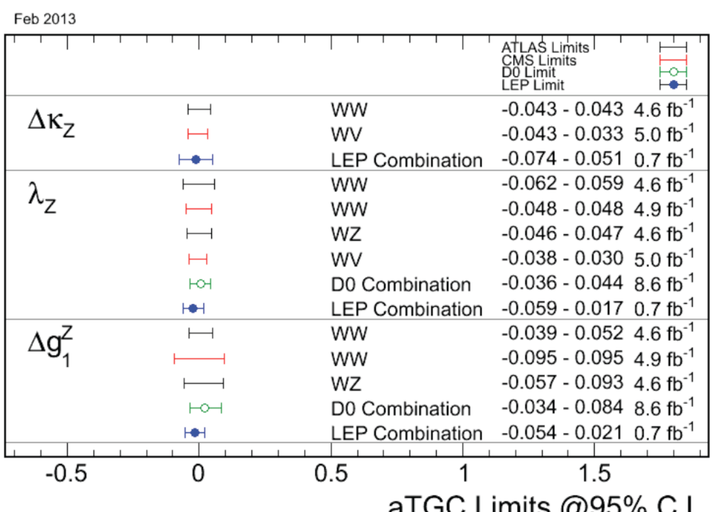
Anomalous TGCs (cont.)

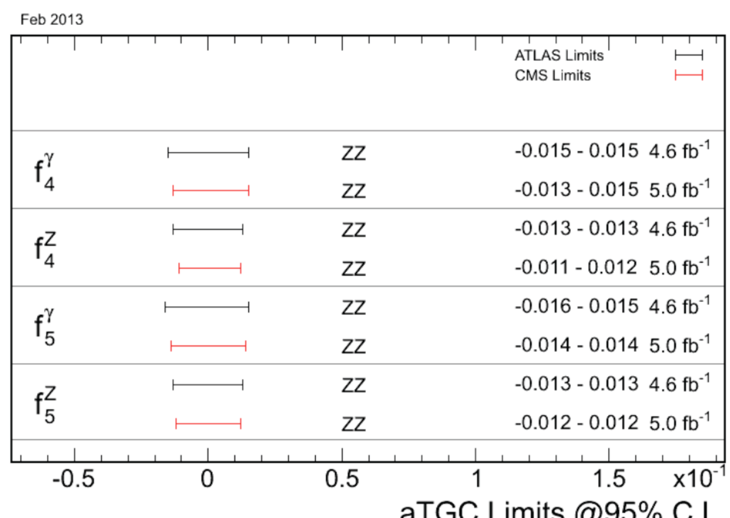
Charged TGCs



Neutral TGCs







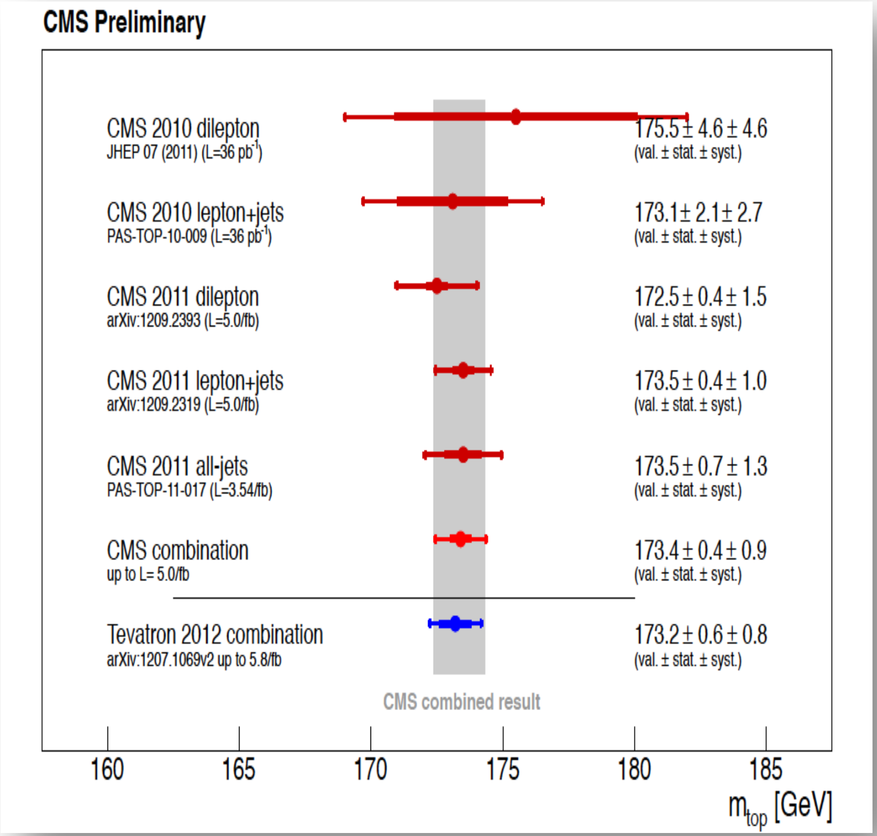
LHC measurements approaching LEP sensitivities

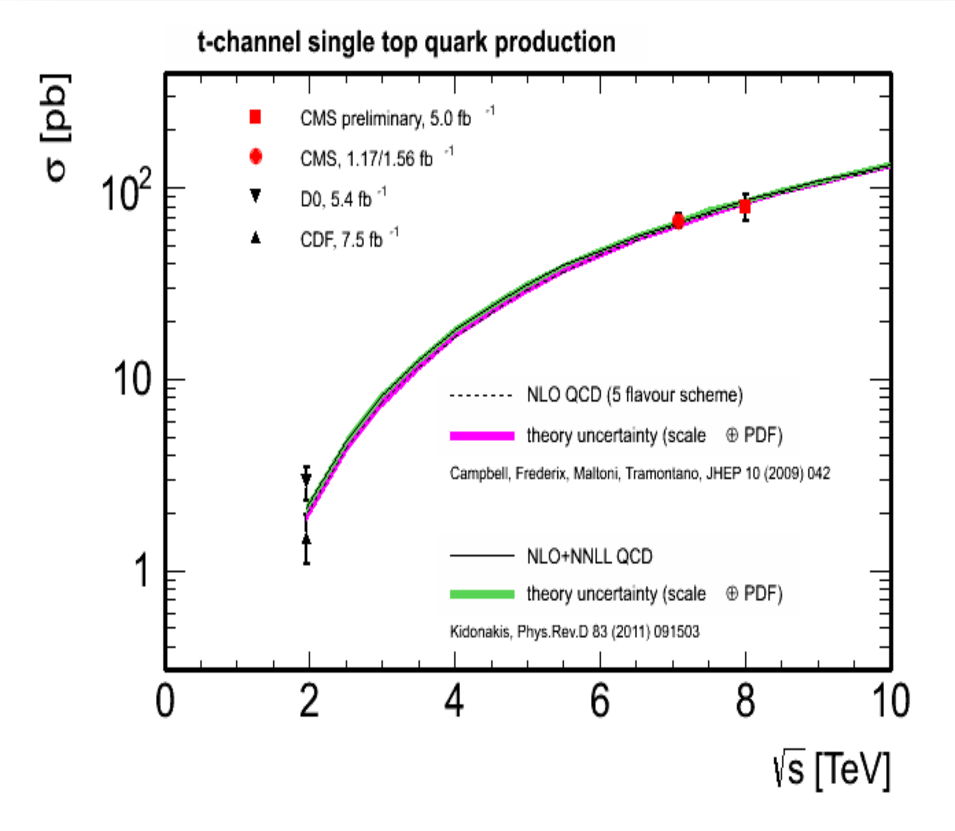
LHC measurements already exceeded LEP sensitivities

Top quark mass and X-section

Top quark mass

Single top quark production





TOP-11-018

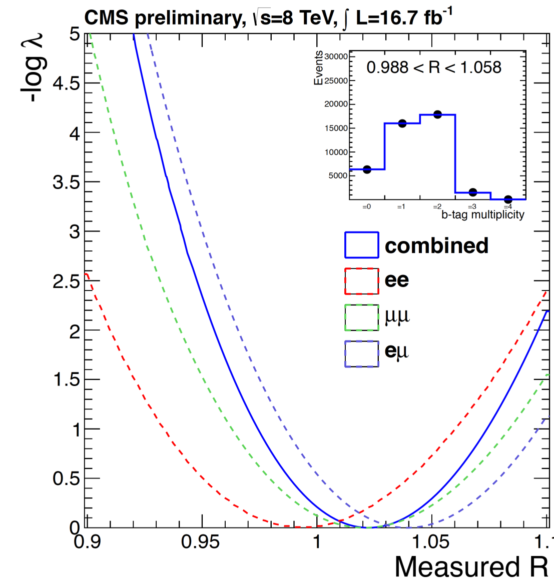
m_{top} = 173.4 ± 0.4 (stat) ± 0.9 (syst) GeV

Ratio B(t→Wb)/B(t→Wq)

- Top events in dilepton channel
- Requires good understanding of b-tagging efficiency and ISR/FSR background jets
- Background estimated from data

$$R = 1.023^{+0.036}_{-0.034}\,(stat. + syst.)$$

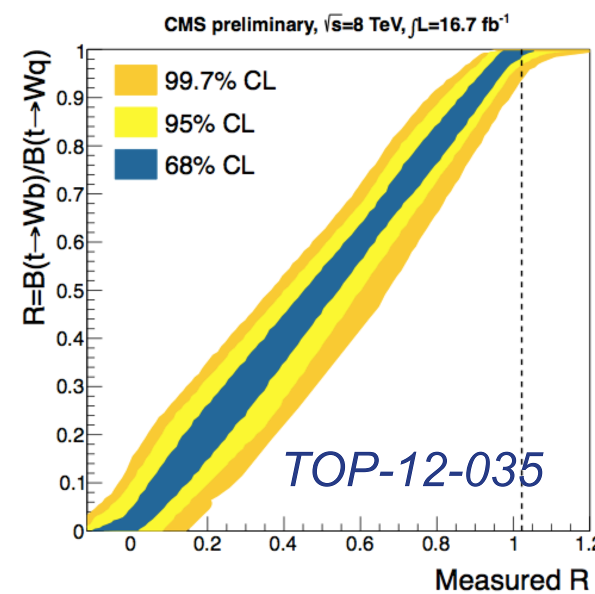
$$\text{If R} \leq 1 \;\rightarrow \text{R} > 0.945 \text{ @ } 95\% \text{ CL}$$



R → $|V_{tb}|$ with the assumption of CKM unitarity and 3 generations

$$R = \frac{B(t \rightarrow Wb)}{\sum_{q=d,s,b} B(t \rightarrow Wq)} = |V_{tb}|^2$$

$$\boxed{\begin{array}{l} |V_{tb}| = 1.011^{+0.018}_{-0.017}\,(stat. + syst.) \\ if\;\; |V_{tb}| < 1 \rightarrow |V_{tb}| > 0.972 \;\; @ \;\; 95\% \;\; CL \end{array}}$$



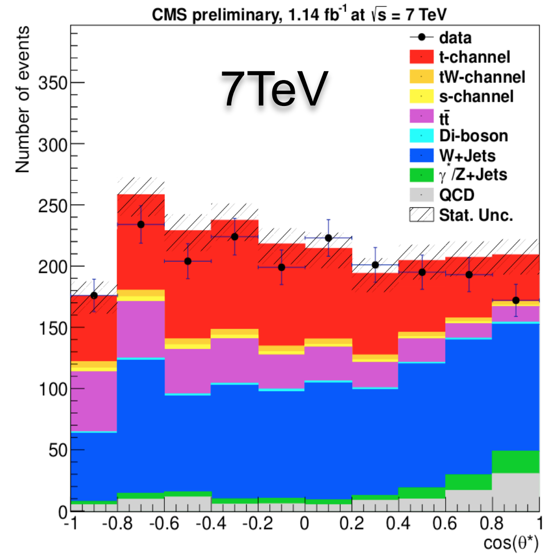
The most precise measurement of R and the most stringent direct lower bound on $|V_{tb}|$.

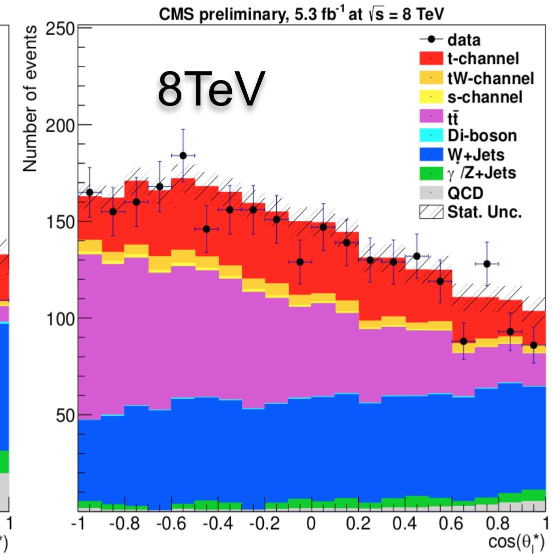
W polarization in single top events

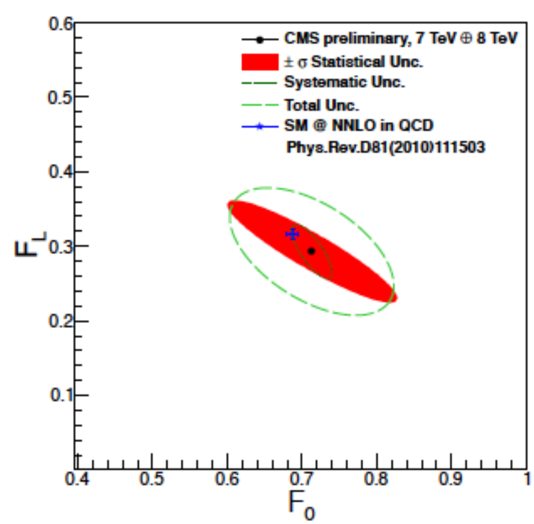
- **First measurement in single-top events (μ+jets)**
- Helicities obtained from likelihoods with reweighted signals.
  - Helicity fractions and W+jets contribution simultaneously extracted.
- **Consistent with the SM and with the measurement in ttbar channels**

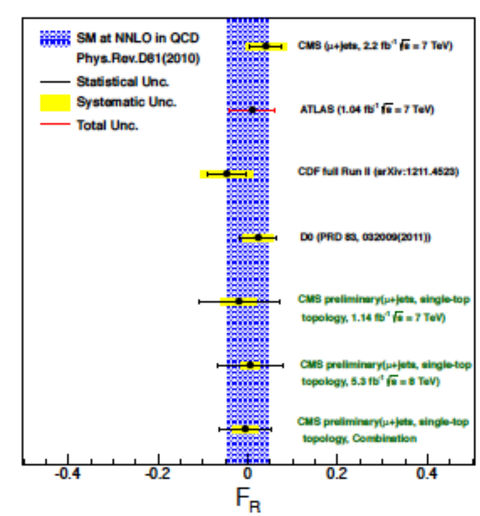
$$F_L = 0.293 \pm 0.069(stat.) \pm 0.030(syst.)$$
$$F_0 = 0.713 \pm 0.114(stat.) \pm 0.023(syst.)$$
$$F_R = -0.006 \pm 0.057(stat.) \pm 0.027(syst.)$$

TOP-12-020







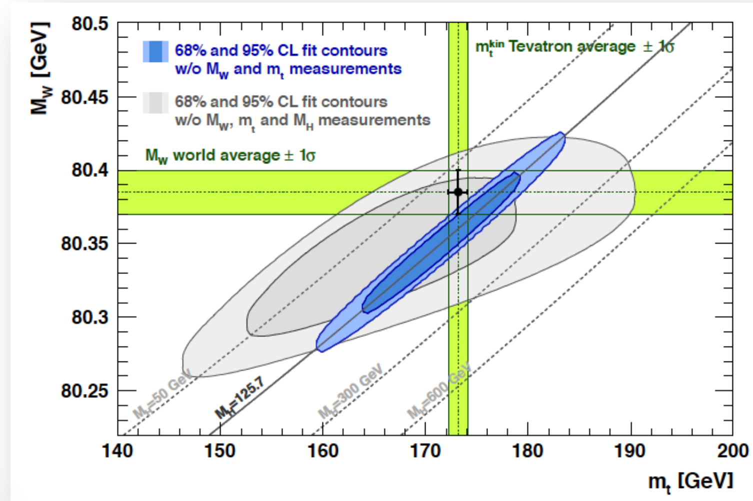


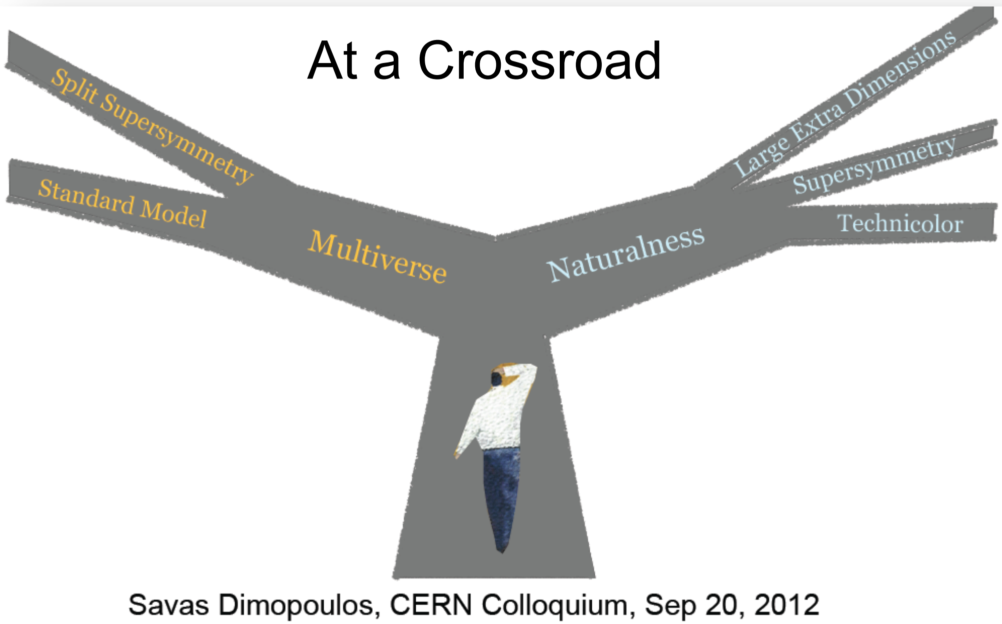
Beyond Standard Model Searches

The standard model and beyond

Standard Model

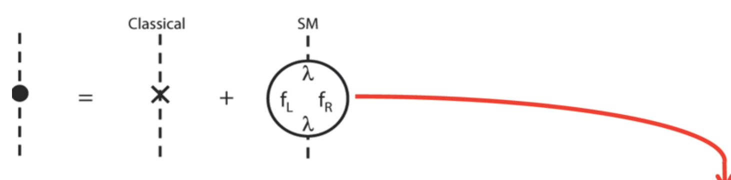
The astonishing brain power of a certain ape species





Higgs mass is a huge problem:

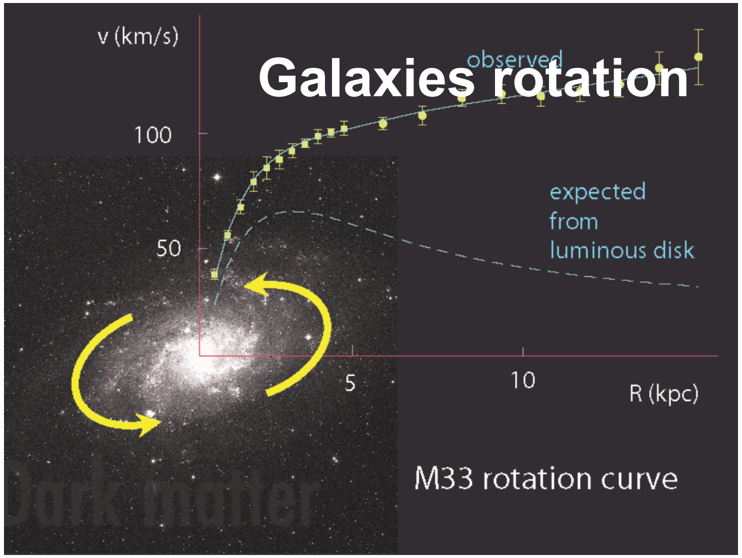
Miraculous cancelations are needed to keep the Higgs mass < 1 TeV

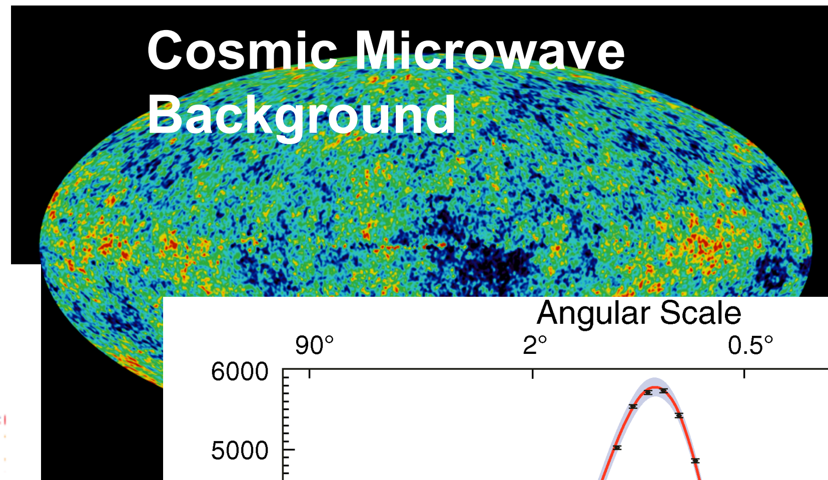


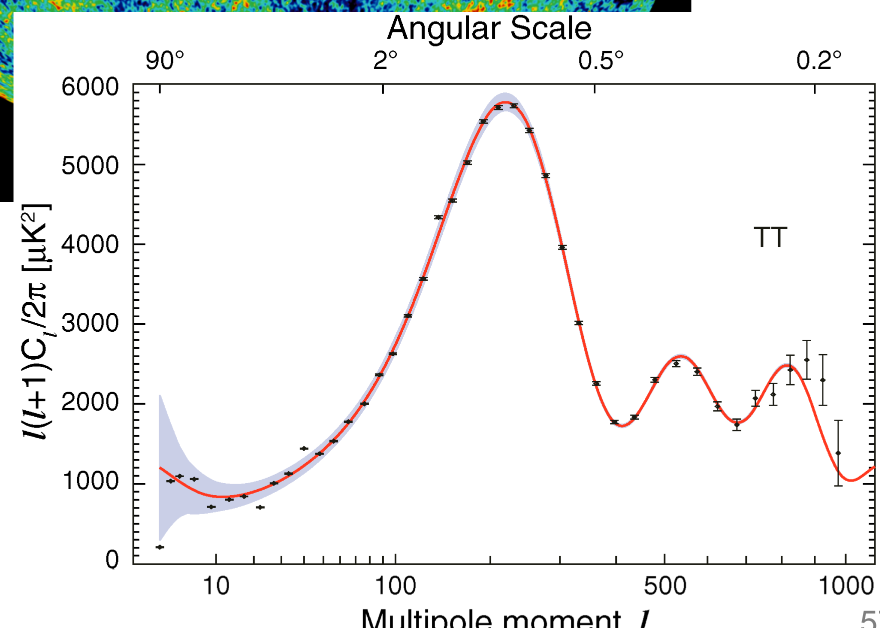
$$m_h^2 = (m_h^2)_0 - \frac{1}{16\pi^2}\lambda^2\Lambda^2 + \ldots ,$$

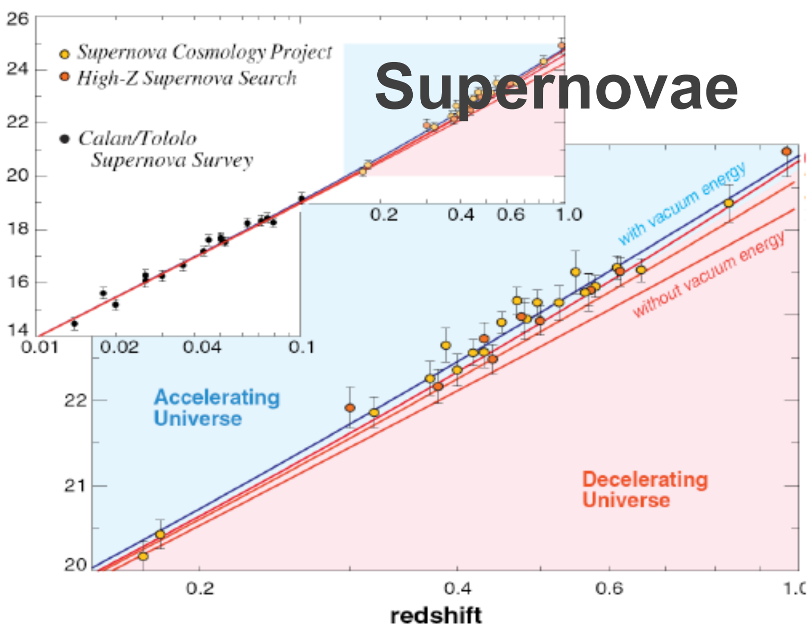
The connection to cosmology

Precision cosmology measurements give strong motivations for new physics:
Galaxies rotations, accelerating expansion, CMB uniformity, space flatness







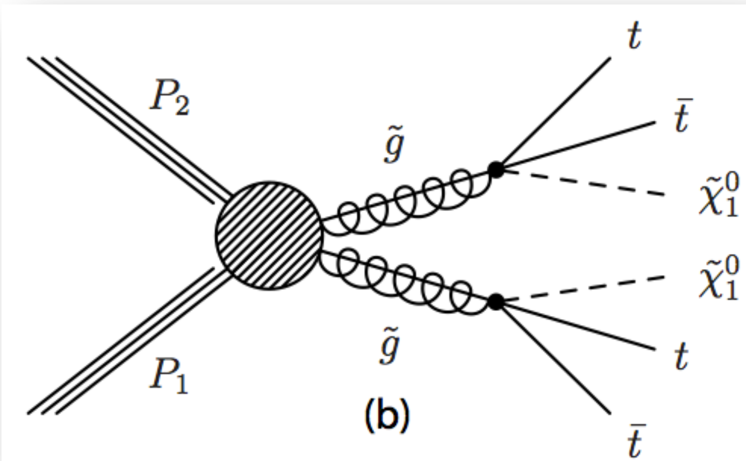


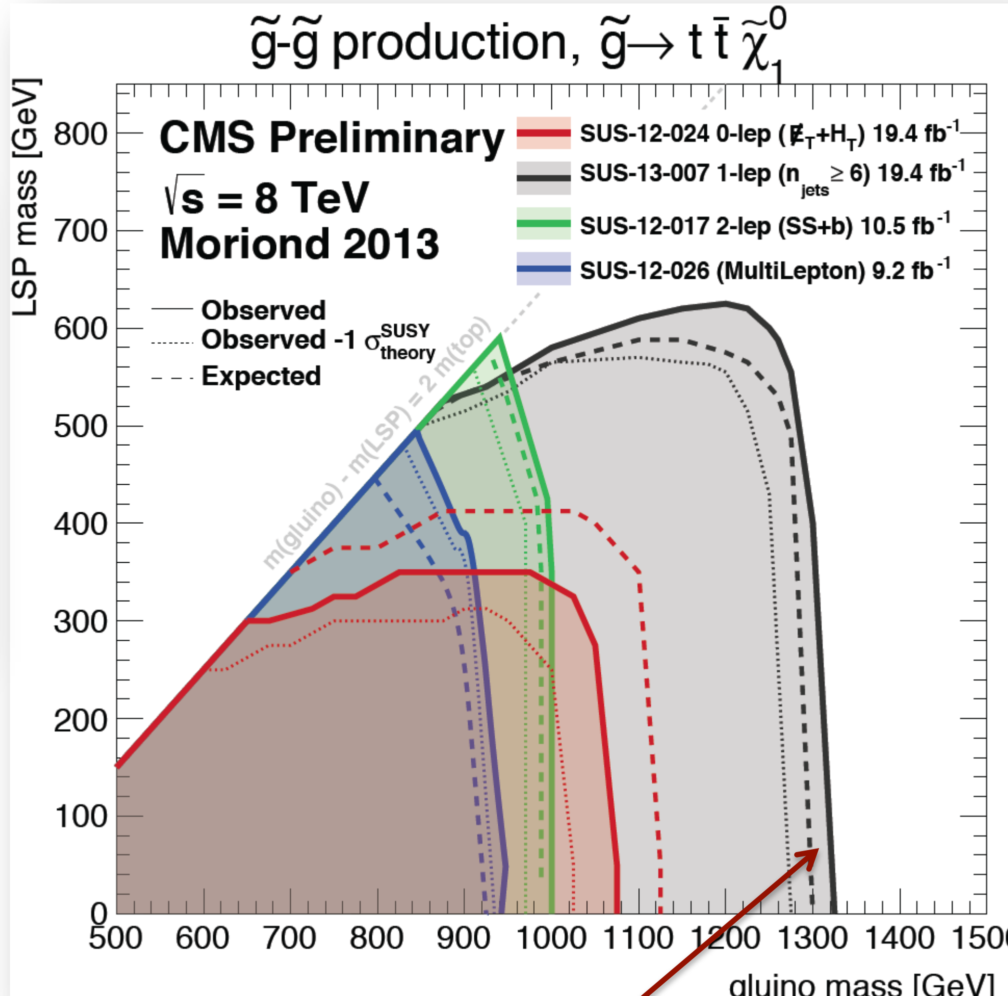
Looking for natural SUSY

- Relatively light stops are needed for naturalness
- Search for stops and sbottoms in gluino decays
  - In natural SUSY the gluino cannot be too heavy
  - If the other squarks are very heavy, then the gluino will decay into sbottoms and stops with high BR
- Search for direct stop and sbottom pair production
  - To close the loophole that the “gluino is too heavy”

gluino→stop searches

Limits in simplified models





1 lepton + ≥6 jets + ≥2 b jets

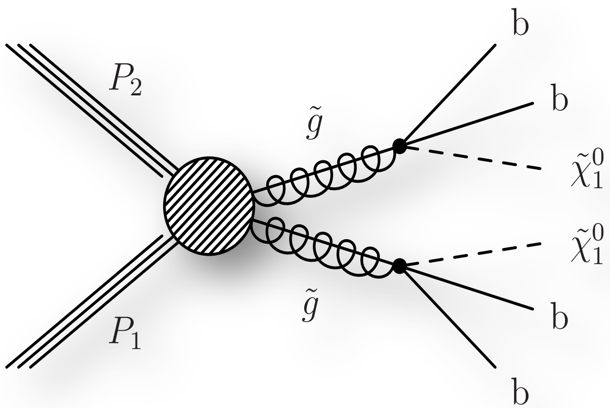
Assumptions:

$$m_{\tilde{t}} > m_{\tilde{g}}$$

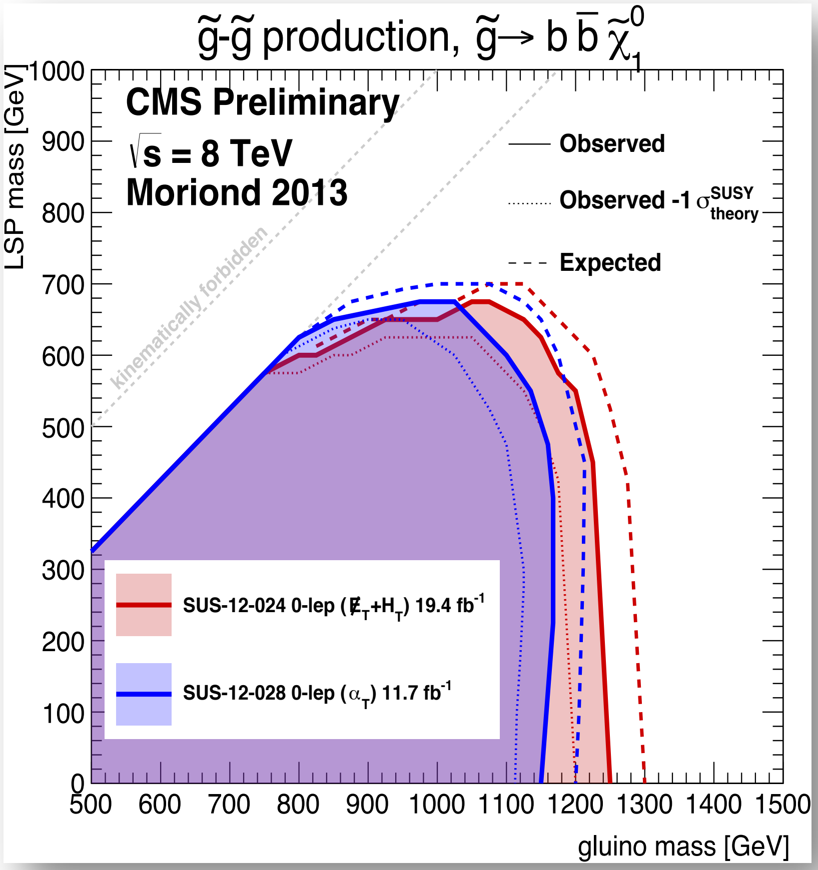
$$\mathrm{BR}(\tilde{g} \rightarrow t\bar{t}\tilde{\chi}_1^0) = 100\%$$

gluino→sbottom searches

Search for gluino decaying to sbottom then bottom quarks and neutralinos



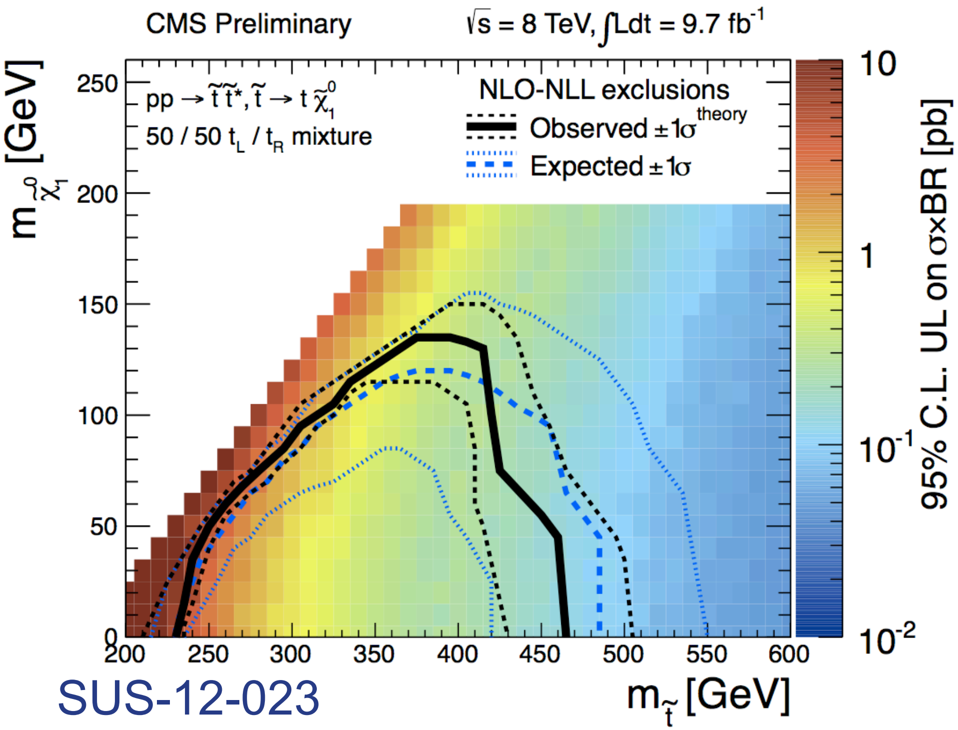
SUS-12-024
SUS-12-028



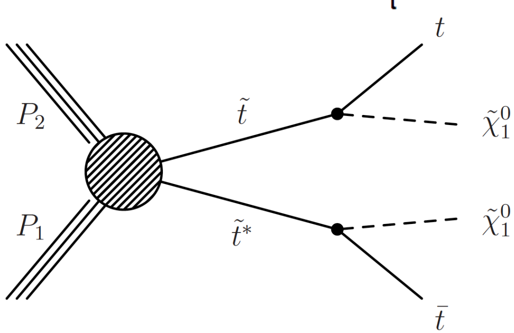
Direct stop and sbottom pair production

Single lepton + missing E_T

$$\tilde{t} \rightarrow t\chi_1^0 \text{ and } \tilde{t} \rightarrow b\chi_1^+ \rightarrow bW\chi_1^0$$

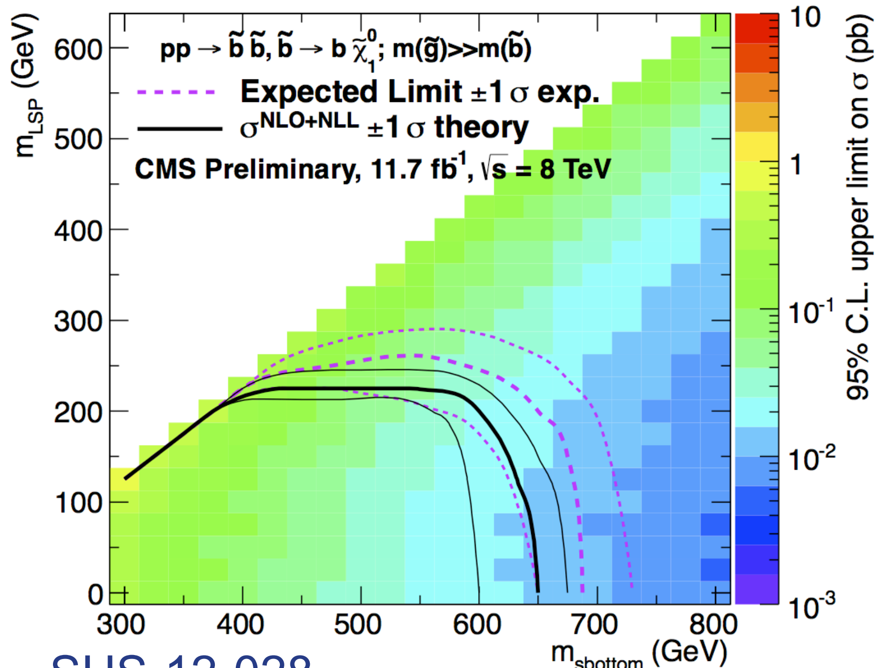


SUS-12-023

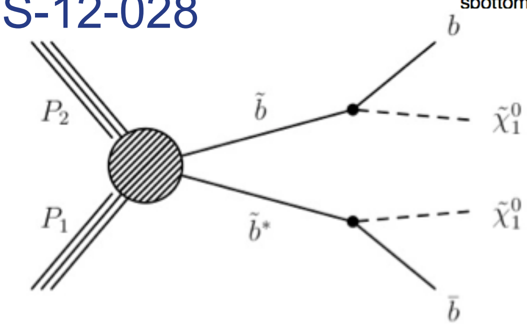


Missing E_T and b jets

$$\tilde{b} \rightarrow b\,\tilde{\chi}_1^0$$

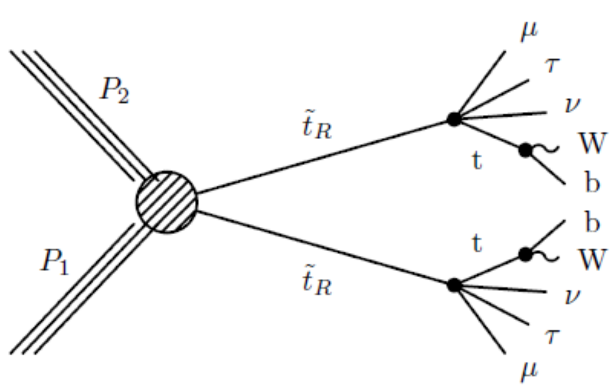


SUS-12-028

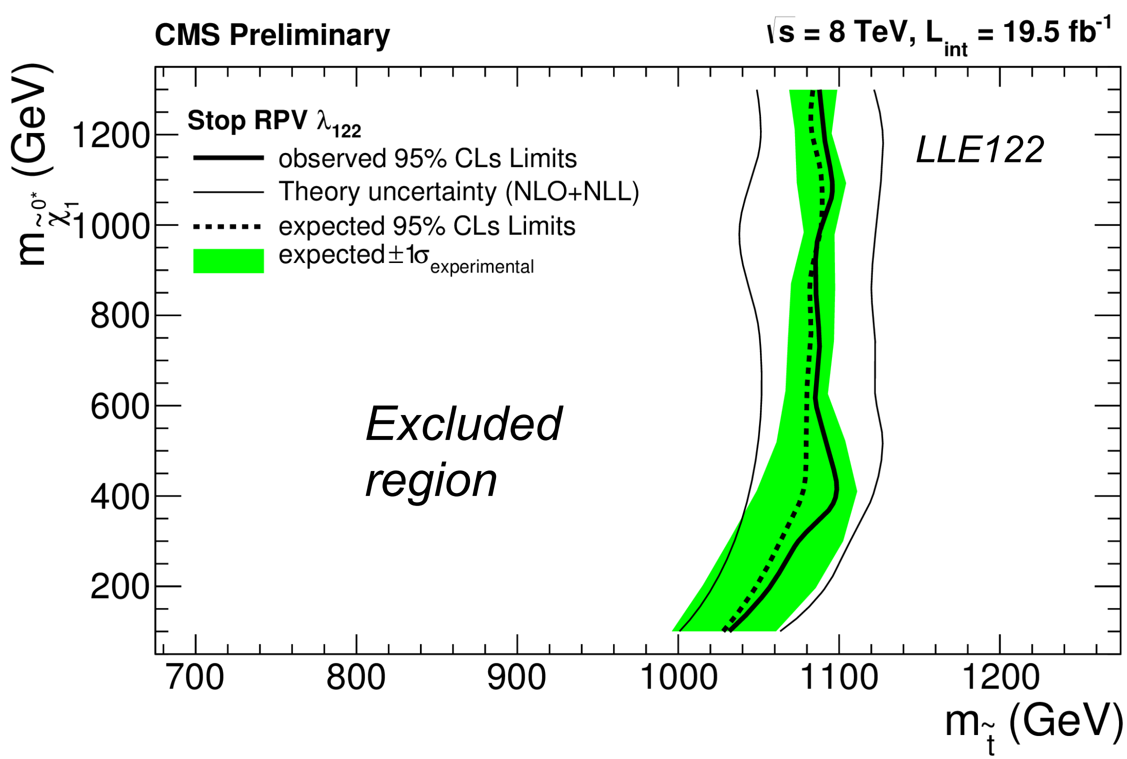


Search for RPV stop

- R-parity violation
  - No stable SUSY particle → less MET than conventional SUSY
- ≥3 leptons+b
  - Including up to 1 τ→had



SUS-13-003

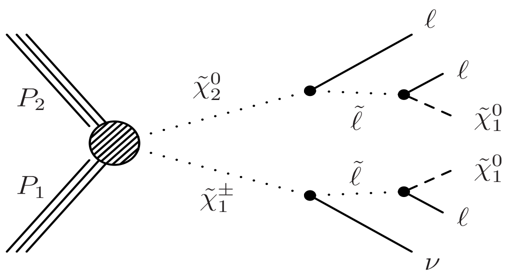


$\chi^{+}\chi^{0}$ searches

SUS-12-022

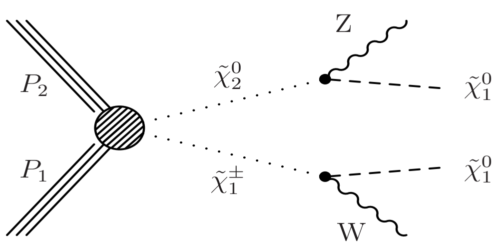
Models with decays into sleptons

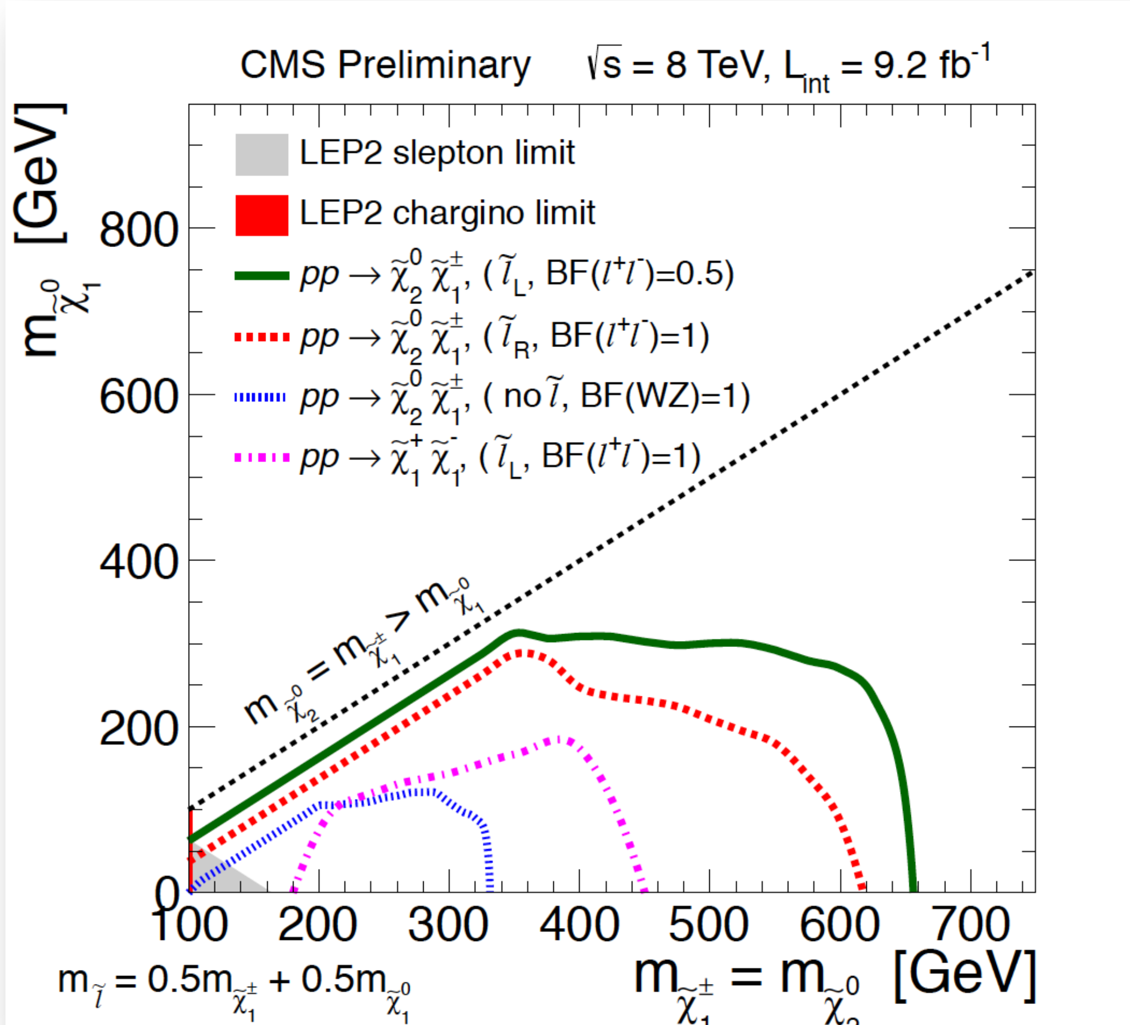
- Trilepton + MET
- Same-sign dileptons



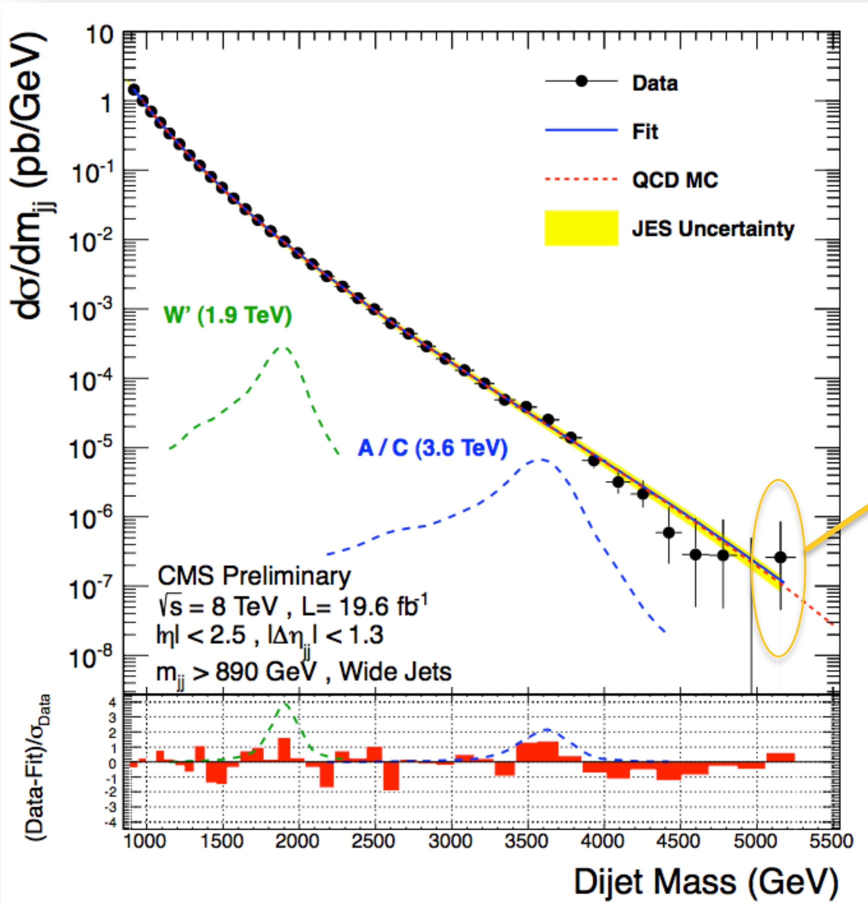
Models with decays into W and Z

- Z→ℓℓ + ℓ + MET
- Z→ℓℓ + W/Z→jet-jet + MET
- Four leptons

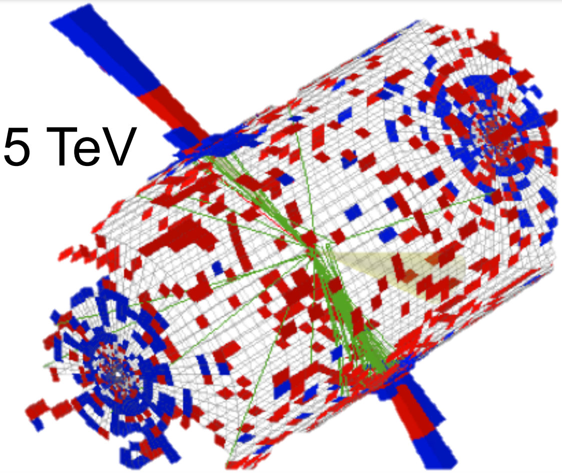


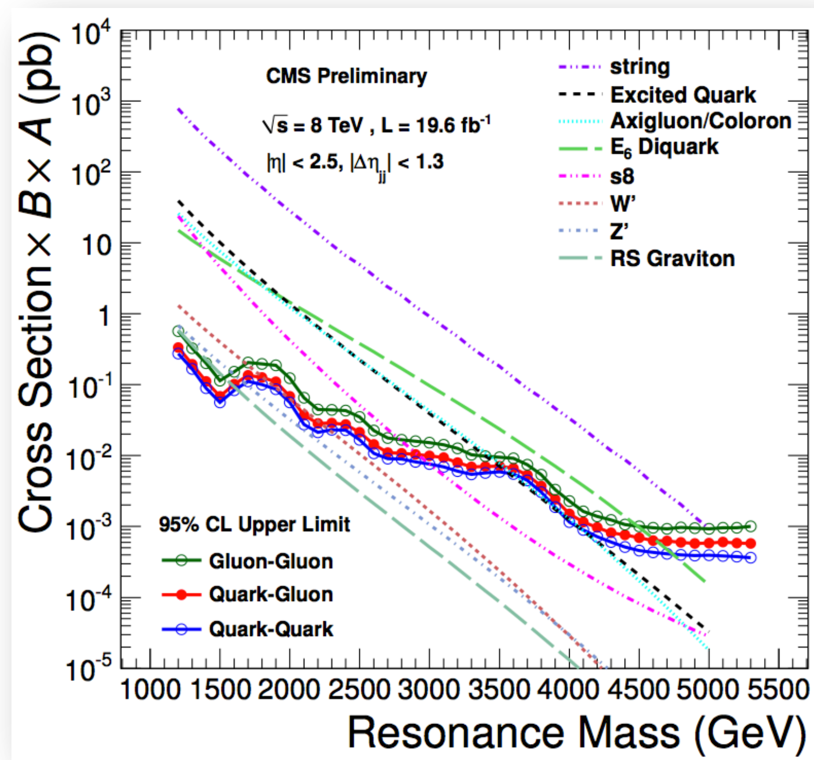


Dijet Resonance Search



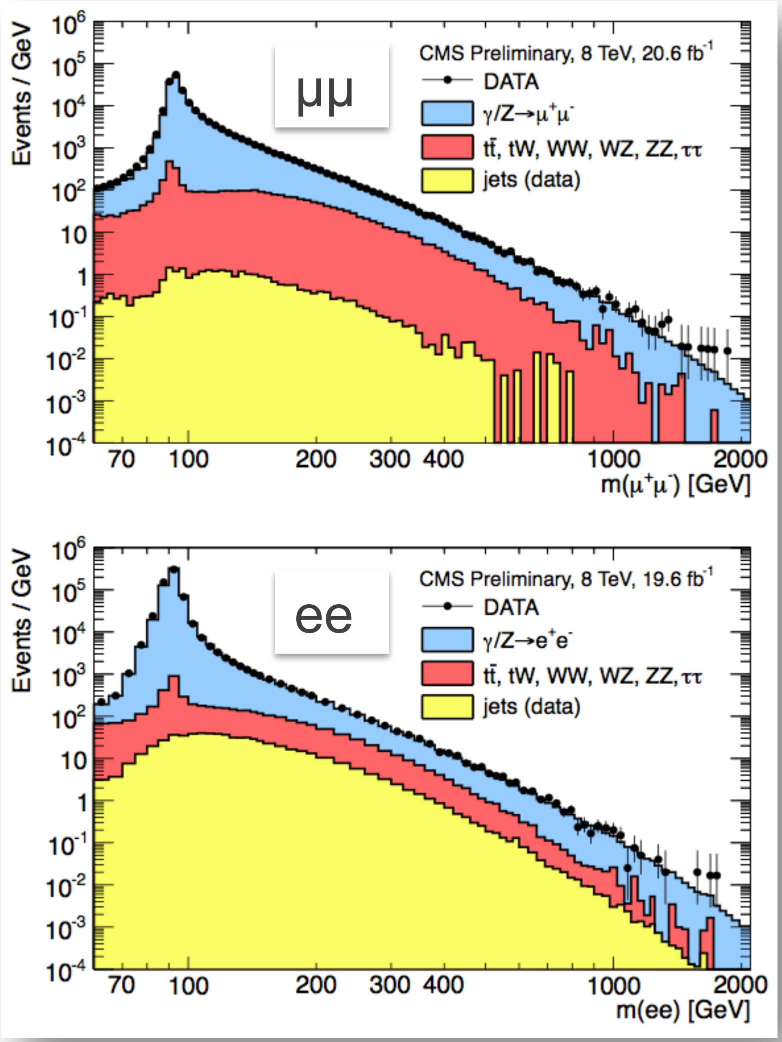
M_{jj} = 5.15 TeV



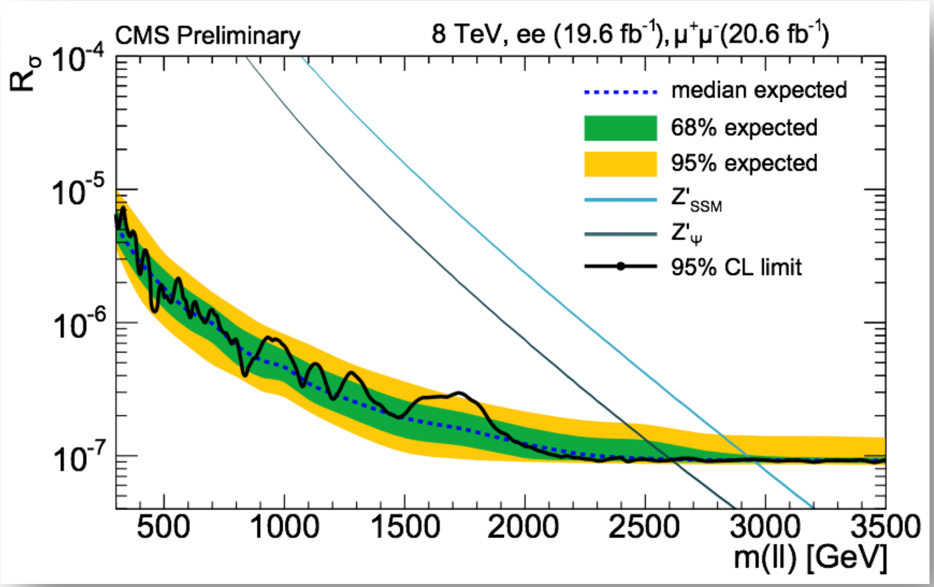


EXO-12-059

Dilepton resonance search



- Z' → e+e-/μ+μ-
- Data to almost 2 TeV, limits to almost 3 TeV

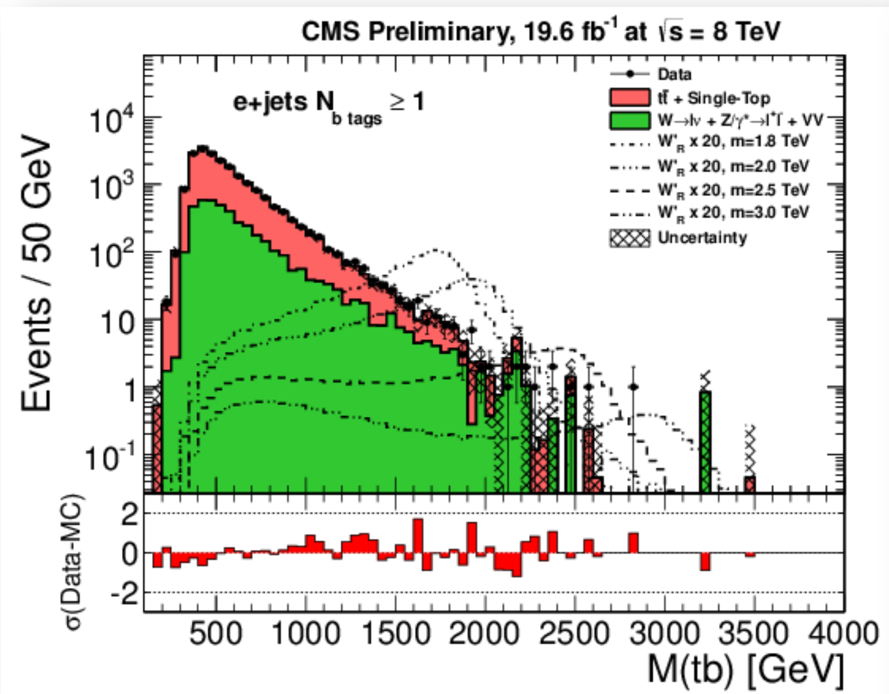


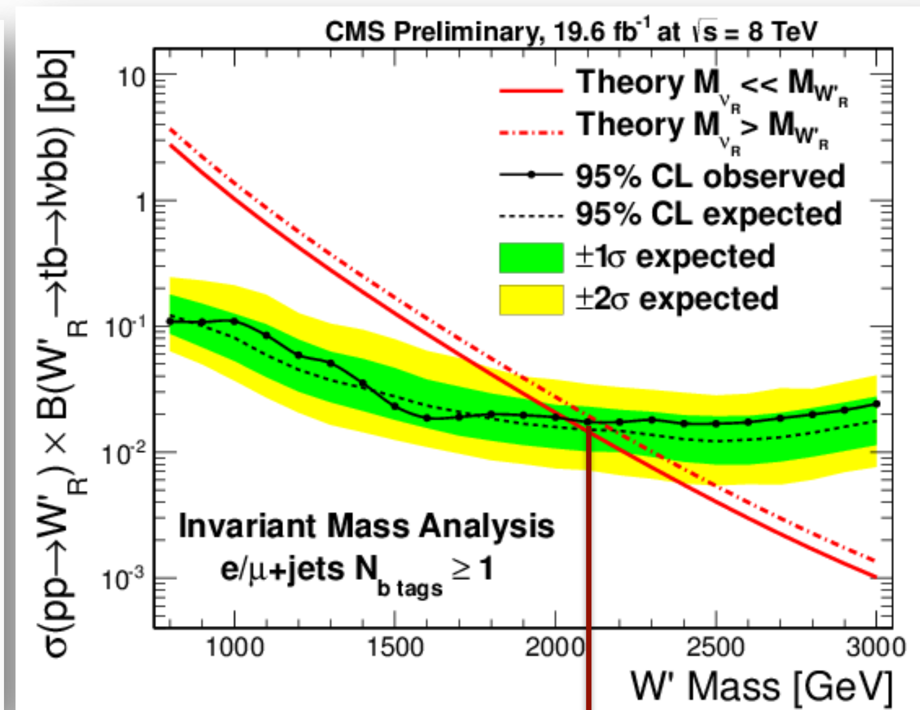
EXO-12-061

W'→tb search

- Heavy W'
  - Predicted by little Higgs, extra dimensions, technicolor, etc
- Lepton+jets+MET signature
  - Use W,t mass constraints to solve for neutrino momentum and reconstruct W' mass

B2G-12-010





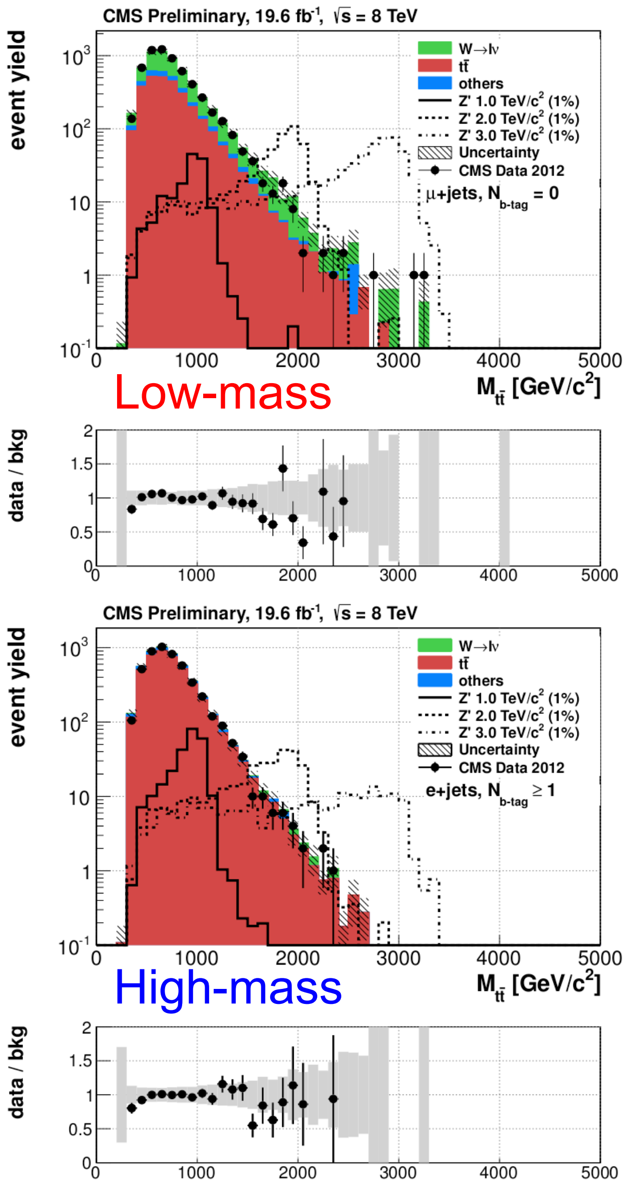
Exclude < 2.1 TeV

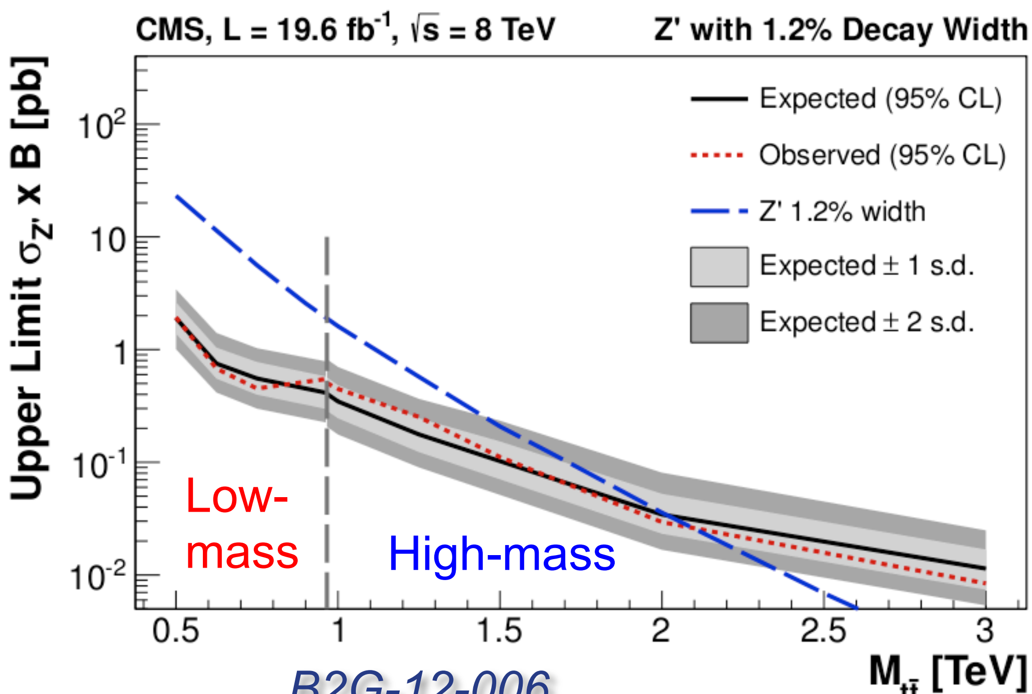
Search for tt resonances

New search for tt-resonances in the l+jets +MET channel with full Run 1 data

– Optimized separately for low-mass (non-boosted, M_{tt} < 1 TeV) and high-mass (boosted) regimes

– Sets most stringent limits today

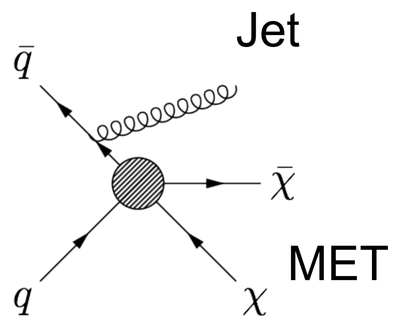


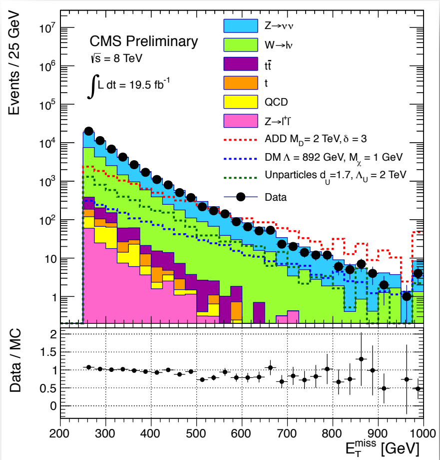


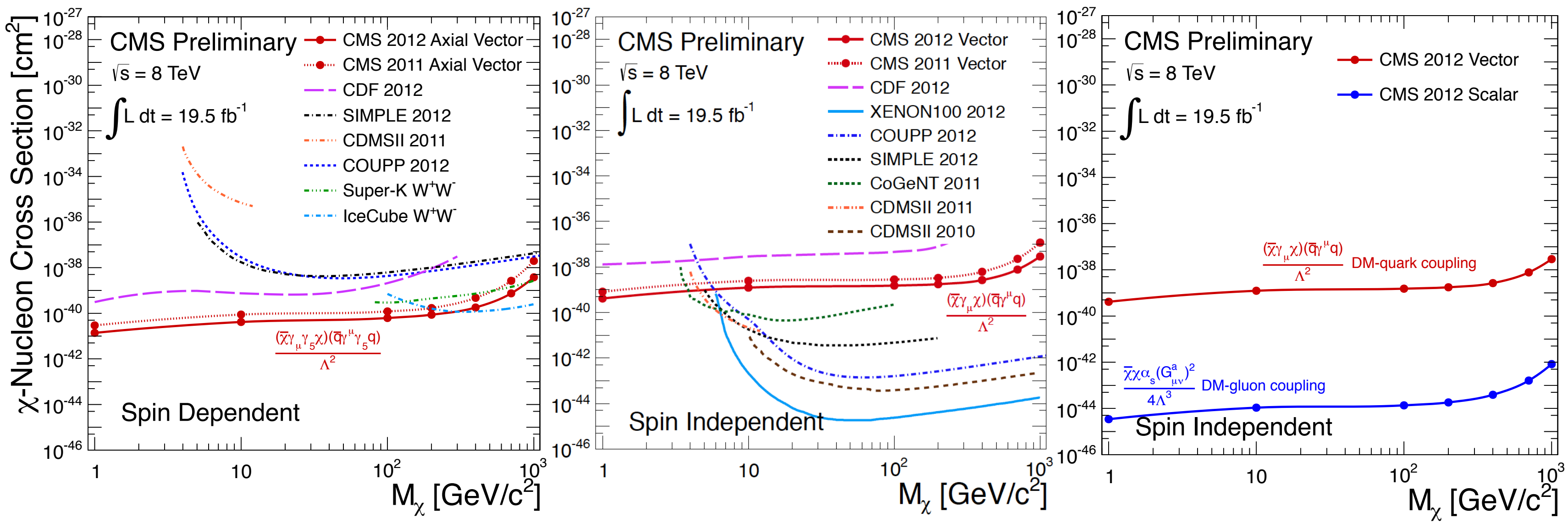
B2G-12-006

Monojets for Dark Matter

- Stringent limits
  - on extra dimensions and dark matter in the monojet channel
- Probing gluon-DM interactions
  - inaccessible to the direct experiments

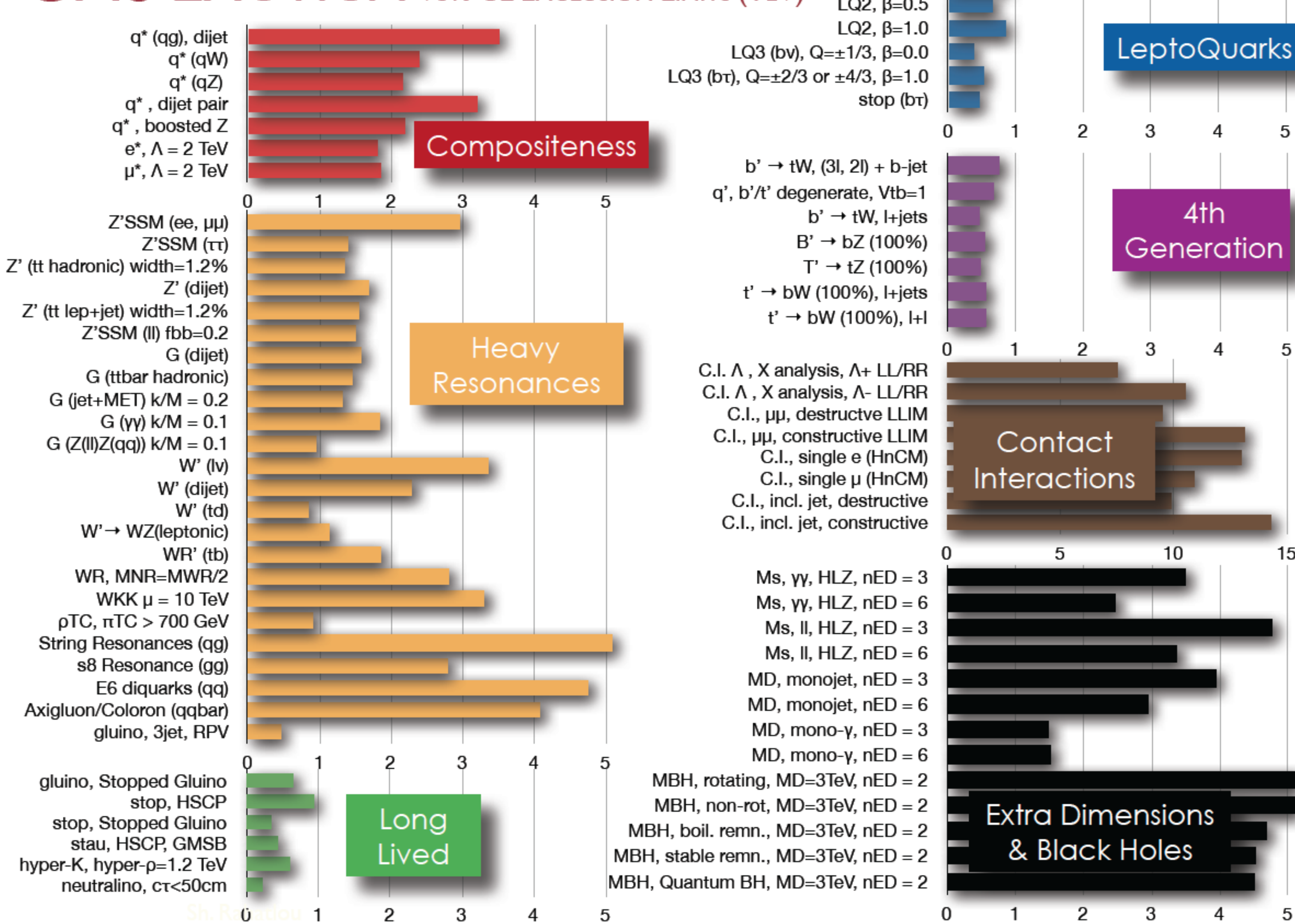






EXO-12-048

CMS Exotica 95% CL Exclusion Limits (TeV)



Outlook

- LHC achieved an astonishing performance in Run 1.
- CMS succeeded to meet all challenges, and to produce an unprecedented wave of physics results (> 230 papers).
- Many new measurements with full proton-proton dataset collected in 2011-12 (~25 fb^{-1}). The agreement of data with the Standard Model is impressive.
- In the $H \to ZZ(4l)$ channel, a signal significance of 6.7σ is now observed. In $H \to \gamma\gamma$ updated results on the signal strength, $\mu = \sigma/\sigma_{SM} \sim 0.8 \pm 0.3$.
- Two independent determinations of the Higgs mass: 125.8±0.6 GeV, in $H \to ZZ(4l)$; and 125.4±0.8 GeV, in $H \to \gamma\gamma$.

Outlook (cont.)

- The pure pseudoscalar hypothesis is excluded at 99.8% C.L. and simple spin 2 models are excluded with greater than 99.4% C.L.
- Strong evidence is seen in $H \rightarrow \tau\tau$ channel (significance ~3σ).
- These measurements strongly indicates that the new particle is a Higgs boson, responsible for the Electroweak Symmetry Breaking.
- However they are still fall from the precision required to rule out all BSM scenarios.
- No evidence of new physics in the 7-8 TeV data (even if we may still have surprises) creates a big expectation on the LHC restart at 13 TeV in 2015.